# Assessment of mitral annuloplasty ring by cardiac computed tomography: Correlation with echocardiographic parameters and comparison between two different ring types

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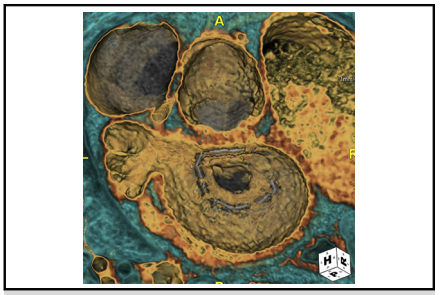
## ABSTRACT

**Objectives:** This study investigated computed tomographic (CT) appearance after mitral ring annuloplasty, especially comparing CT findings between patients with normal pressure gradient (PG) and patients with functional mitral stenosis (MS) and between 2 commonly used types of annuloplasty ring.

**Methods:** A total of 45 cardiac CT scans in patients who underwent mitral ring annuloplasty (Carpentier-Edwards ring, n = 27; Duran ring, n = 18) were retrospectively reviewed. On CT scan, presence of significant pannus around the annuloplasty ring, presence of leaflet thickening, and maximal mitral opening area were analyzed. CT findings were compared between patients with normal PG and patients with functional MS (mean diastolic PG $\geq$ 5 mm Hg). Incidences of functional MS and CT findings were compared between ring types.

**Results:** Significant pannus was present in 10 cases and leaflet thickening in 31 cases, and maximal opening area was 2.34 $\pm$ 0.717 $cm^2$. Valve opening area on CT was positively correlated with mitral valve area on transthoracic echocardiography and negatively correlated with mean diastolic PG. Mean diastolic PG was significantly elevated with increasing pannus severity. Patients with functional MS had more significant pannus than patients with normal PG. The Duran ring group had higher mean diastolic PG, smaller mitral valve area, and higher incidence of functional MS than the Carpentier-Edwards ring group ($P < .05$). The proportion of pannus and significant pannus was significantly higher in the Duran ring group ($P < .05$).

**Conclusions:** Significant pannus around the annuloplasty ring on CT may cause functional MS after mitral ring annuloplasty. This may occur more frequently with the Duran ring. (J Thorac Cardiovasc Surg 2015;150:1082-90)




Computed tomographic image shows severe pannus causing mitral stenosis in a Duran annuloplasty ring.

**Central Message**

Pannus around the annuloplasty ring seen on computed tomography may cause functional mitral stenosis after mitral ring annuloplasty and may occur more frequently with the Duran ring.

**Perspective**

Mitral stenosis after mitral valve annuloplasty is mostly caused by pannus from the annuloplasty ring and is related to annuloplasty ring type. On computed tomography after mitral valve annuloplasty, patients with functional mitral stenosis had more significant pannus formation, and the Duran ring had a higher incidence of pannus formation and a smaller opening area than the Carpentier-Edwards ring. Cardiac computed tomography can help to evaluate pressure gradient elevation in patients with the Duran ring.

See Editorial Commentary page 1091.

Mitral valve (MV) repair is widely regarded as the procedure of choice for significant nonrheumatic mitral regurgitation requiring surgery. Recurrent mitral regurgitation is the most common cause of failure of MV repair, but mitral stenosis (MS) is relatively rare after MV repair performed to correct mitral regurgitation caused by myxomatous disease or ischemic MV disease.[1-5] MS after ring annuloplasty has been reported to be mostly caused by pannus overgrowth

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**Abbreviations and Acronyms**
MV = mitral valve
MS = mitral stenosis
CT = computed tomography
PG = pressure gradient
TTE = transthoracic echocardiography
CE = Carpentier-Edwards
MVA = mitral valve area

from the annuloplasty ring, and the type of annuloplasty ring used has been believed to be related to pannus development.[6-10] Pannus formation is considered to be a foreign-body reaction to the synthetic annuloplasty ring and has been observed frequently after insertion of the flexible Duran annuloplasty ring (Medtronic, Inc, Minneapolis, Minn).[6-10]

Recently, cardiac computed tomography (CT) has emerged as a novel technique to evaluate cardiac valves, including prosthetic valves. Little is known, however, regarding CT appearance after MV repair. We hypothesized that CT findings after MV ring annuloplasty might differ according to echocardiographic parameters and different types of annuloplasty rings.

The purpose of our study was to investigate CT appearance after mitral ring annuloplasty, especially to compare CT findings between patients with normal pressure gradient (PG) and patients with functional MS on transthoracic echocardiography (TTE), and between two commonly used types of annuloplasty ring (flexible Duran ring and rigid Carpentier-Edwards [CE] ring [Edwards Lifesciences Corporation, Irvine, Calif]).

## MATERIALS AND METHODS

### Patients

The institutional review board of our institution approved this retrospective study, and informed consent was waived. From surgical records from January 1995 to December 2013, we retrieved data on 846 patients who underwent MV repair in our institution. Of them, 356 had been included in the study population of a prospective, randomized trial conducted in our institution from January 1995 to August 2005.[11] Among these patients, we included 68 patients who had undergone mitral annuloplasty and who had undergone cardiac CT from March 2008 to August 2014. Patients with an interval of less than 1 year between mitral annuloplasty and CT (n = 13), patients with rheumatic valve disease as original etiology (n = 6), patients with no ring or with other ring types than the CE ring or Duran ring (n = 3), and patients with nonassessable image quality of CT scans as result of severe artifacts (n = 2) were excluded from the study (Figure 1). A total of 45 patients were included in the final analysis; patients received either a CE Classic ring or a Duran ring during their operation. Demographic data and information on the annuloplasty ring were collected from electronic medical records. Patients underwent cardiac CT for suspected coronary artery disease (n = 18), evaluation of coronary bypass graft (n = 18), suspected MV dysfunction on TTE (n = 5), and pulmonary vein evaluation before radiofrequency ablation (n = 4).

### CT Acquisition

All CT scans were performed with a dual-source CT scanner (SOMATOM Definition Flash; Siemens Healthcare, Forchheim, Germany) or a 64-slice multidetector CT (Somatom Sensation 64; Siemens Medical Solution, Erlangen, Germany). In the absence of contraindications, patients with a heart rate greater than 65 beats/min received 50 mg of an oral $\beta$-blocker (metoprolol tartrate) 1 hour before examination and a 0.3-mg sublingual dose of nitroglycerin were administered just before the scan. Scans were performed with retrospectively electrocardiographically gated data acquisition or prospectively electrocardiographically gated acquisition mode according to the CT indication. For each patient, the appropriate interval between injection of the contrast agent and initiation of scanning was determined by the timing bolus technique. After a bolus injection of 10 mL of iopamidol (Pamiray, 370 mg of iodine/mL; Dongkook Pharma, Seoul, Korea) followed by 20 mL of saline solution at 5 mL/s, optimal delay times were determined by automatic evaluation of the contrast enhancement in the ascending aorta. All CT scans were performed with the triple-phase injection method (70 mL of iopamidol followed by 30 mL of 30% blended iopamidol with saline solution and 20 mL of saline solution at 5 mL/s).

Image reconstruction was performed with a medium kernel (b36f), and the reconstruction slice thickness was 0.75 mm with 0.5-mm increments. For all patients, 10 transverse data sets were reconstructed for every 10% of the cardiac cycle (0% to 90%). Reconstructed images were transferred to an image server and analyzed with dedicated 3-dimensional software (Aquarius iNtuition, version 4.4.11; TeraRecon, Inc, San Mateo, Calif).

### Image Analysis

All CT analyses were performed by a single radiologist (Y.J.S.), who was blinded to clinical information and TTE results. Valve evaluation was performed with multiplanar reformatted images in a short-axis image of the MV annulus, a long-axis view of the left ventricle, and a 4-chamber view. Assessment of MV and annuloplasty ring consisted of evaluation of pannus formation, valve leaflet thickening, valve opening area, diastolic opening angle, and systolic coaptation angles of anterior and posterior mitral leaflets, tenting height and mitral annular size. The short-axis view of the mitral annulus was used to evaluate the presence of pannus around the annuloplasty ring. If a low-attenuating pannus was present, the severity of pannus was evaluated by both qualitative and quantitative methods. For qualitative assessment, pannus severity was visually graded according to the proportion of the diameter of the narrowest area by the pannus to the area inside the annuloplasty ring and classified as insignificant or significant. Pannus was considered to be significant if the narrowing as a result of the pannus was more than 50% of the diameter. For quantitative assessment, the area inside the annuloplasty ring and inside the pannus at the mitral annular level was measured, and the proportion of the area inside the pannus to the area inside the annuloplasty ring was calculated (Figure 2). For evaluation of valve leaflet thickening, the maximal thickness of the MV leaflet was measured, and the leaflet was considered to be thickened when leaflet thickness was greater than 2 mm.[12] In cases in which multiphase data were available, the opening area of the MV was measured at the maximal opening point of the valve tip.[13] The diastolic opening angle and systolic coaptation angles of the anterior and posterior mitral leaflets and the tenting height on systole were quantified in a 4-chamber view.[14,15] For assessment of mitral ring size, the maximal and minimal diameters inside the annuloplasty ring were measured at the diastolic phase (maximal opening point of the MV). The annular area was defined as the area within the annuloplasty ring on a short-axis view. The annular sphericity index was calculated by dividing the maximal annular diameter by minimal diameter, which was modified from echocardiographic measurements.[16]

### Data Analysis

Clinical data were collected from medical records for etiology of original valve disease, type and size of annuloplasty ring, concurrent other