Apical conicity ratio: A new index on left ventricular apical geometry after myocardial infarction

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Objective: Our objective was to introduce a new index to evaluate left ventricular aneurysm by quantitative analysis of left ventricular apical geometry.

Methods: A total of 116 selected subjects underwent magnetic resonance imaging, 28 healthy volunteers, 29 patients with dilated cardiomyopathy, and 59 patients with ischemic heart disease (26 with left ventricular aneurysm; 33 with no aneurysm). The apical conicity ratio was calculated as the ratio of left ventricular apical area over apical triangle.

Results: Diastolic apical conicity ratio of patients with left ventricular aneurysm was 1.62 $\pm$ 0.20 and systolic apical conicity ratio was 1.78 $\pm$ 0.43. After left ventricular reconstruction, the diastolic apical conicity ratio decreased to 1.47 $\pm$ 0.23 and the systolic ratio to 1.51 $\pm$ 0.21, which came close to the normal level, whereas other global indices remained. In patients with dilated cardiomyopathy, sphericity index and eccentricity index increased significantly without changes in the apical conicity ratio. Among patients with ischemic heart disease, the apical conicity ratio of the group with left ventricular aneurysm was significantly higher than that of the group without an aneurysm when the other indices between the 2 groups showed no statistically difference. Receiver operating characteristic curves showed only apical conicity ratio had high power of discriminating left ventricular aneurysm from no aneurysm.

Conclusions: The new index, apical conicity ratio, can be used to quantify the regional left ventricular deformation, especially in patients with left ventricular aneurysm resulting from myocardial infarction. (J Thorac Cardiovasc Surg 2010;140:1402-7)

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Ventricular remodeling is an inevitable pathophysiologic process in the heart after acute myocardial infarction and may contribute to heart failure, left ventricular aneurysm (LVA), and poor prognosis. Recently, the significance of apical conical configuration in maintaining left ventricular contractile efficiency has been recognized.[1-4] Surgical treatment for LVA involved not only reduction of ventricular volume, but also left ventricular reshaping. How to assess the left ventricular geometry, especially for apical morphology, becomes an issue of concern to the cardiac surgeon. Several indices, such as sphericity index (SI), volumetric sphericity index (vSI), and eccentricity index (EI), are often used to evaluate global left ventricular morphology[5-7] but cannot be used for assessing regional left ventricular deformation. It has been demonstrated in previous studies that Fourier shape analysis[7-10] precisely quantifies left ventricular geometry; nevertheless, it is rarely applied clinically owing to its complex and time-consuming procedure. To date, there is not a clinically useful index of regional left ventricular deformation. In this study, we introduce a new index, apical conicity ratio (ACR), representing the ratio of the area of left ventricular apex over the apical triangle on a 2-chamber view image, which accurately evaluates the extent of apical geometric deviations from normal shape.

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METHODS

Patient Selection

Twenty-six patients with LVA underwent left ventricular reconstruction and surgical revascularization concomitantly. Magnetic resonance imaging (MRI) before and after surgical ventricular restoration was evaluated. The operation was performed with cardiopulmonary bypass and aortic clamping. Moderate systemic hypothermia (28°C–30°C) and antegrade cold blood cardioplegia were used. An incision parallel to the left anterior descending artery

Abbreviations and Acronyms

ACR	= apical conicity ratio
DCM	= dilated cardiomyopathy
EDV(I)	= end-diastolic volume (index)
EI	= eccentricity index
ESV(I)	= end-systoc volume (index)
IHD	= ischemic heart disease
LVA	= left ventricular aneurysm
MRI	= magnetic resonance imaging
ROC	= receiver operating characteristic
SI	= sphericity index
SV(I)	= stroke volume (index)
vSI	= volumetric sphericity index

was made within the infarcted anterior wall segment and any thrombus carefully removed. The junctional borders were visible in most cases; palpation was helpful in the presence of an unclear border. An endoventricular purse-string suture was placed with a 1-0 Prolene polypropylene line (Ethicon, Inc, Somerville, NJ). The suture was placed in the scarred tissue above the junctional zone, and deep bites were made into the half thickness of this tissue to apply sufficient and lasting tension. The suture was then tied to rebuild the ventricular shape and created an opening about 2 cm in diameter. The ventricular chamber was reduced and kept in satisfactory geometry. The ventriculotomy was closed with 1-0 Prolene polypropylene line as heavy horizontal mattress sutures buttressed in polytetrafluoroethylene and reinforced by continuous sutures. In this process, the stitch sites were adjusted occasionally to avoid deforming the ventricular shape.[11,12] If concomitant coronary artery bypass grafting was to be performed, all distal anastomoses were performed during the same aortic crossclamp period, and proximal anastomoses were performed during the rewarming period. The operations were performed by 5 surgeons who were not aware of ACR and the study design. The criterion for patient selection was that the patient undergo coronary artery bypass grafting with a dyskinetic segment exceeding 30% of the left ventricular perimeter on right anterior oblique ventriculography.

Thirty-three patients with ischemic heart disease without LVA (non-LVA), 29 patients with dilated cardiomyopathy (DCM), and 28 healthy volunteers were selected as control. The non-LVA group had 33 patients (23 men and 10 women; mean age 56.0 ± 9.2 years) with previous myocardial infarction, and all of the patients underwent surgical revascularization. The DCM group comprised 29 patients (21 men and 8 women; mean age 44.9 ± 14.8 years) in whom angiography had proved the absence of coronary artery disease. The healthy group included 28 healthy volunteers (26 men and 2 women; mean age 30.6 ± 3.9 years) with no history or physical finding of cardiac or pulmonary disease. All patients with ischemic heart disease (IHD) received preoperative echocardiography and left ventricular angiographic examinations to determine dyskinetic LVA. This study was approved by the Institutional Review Board at Fu Wai Hospital. All patients gave written informed consents.

MRI Technique

A 1.5-T whole-body scanner (Avanto, Siemens Healthcare, Erlangen, Germany) was used for MRI scanning with the subjects in the supine position. The system was capable of operating at a maximum slew rate of 200 mT/m and a maximum gradient strength of 40 mT/m. Twelve-element matrix coils (6 anterior and 6 posterior) equipped with the scanner and wireless physiologic measurement unit were activated for data acquisition wireless vector cardiographic gating triggering.

All imaging acquisitions were captured under breath control. Scout transversal and sagittal images were acquired followed by a half-Fourier acquisition single shot turbo spin echo sequence (HASTE: repetition time/echo time = 700/42 ms, voxel size = 2.5 × 1.5 × 6.0 mm, flip angle = 160°) for the exact determination of long-axis (left ventricle, 2-chamber view: along the line through the base of the heart and the middle of the mitral valve on axial images), 4-chamber (along the line through the base of the heart and the middle of the mitral valve on 2-chamber images), and short-axis (2-chamber view: perpendicular to the line through the base of the heart and the middle of the mitral valve on 4-chamber view) plane position. True imaging with steady-stage precession sequence (TrueFisp) was chosen for cine scan in the long- and short-axis views with the following parameters: repetition time/echo time = 4.0/1.1 ms, voxel size = 2.0 × 2.0 × 6.0 mm, flip angle = 62°; each section was then acquired in a single breath hold in 8 to 14 seconds with 15 to 25 temporal phases per heartbeat.

Contrast-enhanced images were acquired approximately 15 minutes after bolus injection of gadolinium diethylenetriamine pentaacetic acid (Magnevist, Schering, Berlin, Germany; 0.15 mmol/kg or 0.20 mmol/kg) with an inversion-recovery 3-dimensional spoiled gradient echo sequence; inversion time was determined with real-time plan scan. Typical parameters were a field of view of 400–400 mm^2, matrix of 256–256 pixels, slice thickness of 5.00 mm, overlapping slices (50%), flip angle of 15°, time to echo of 1.36 ms, and time to repeat of 4.53 ms.

Imaging Analysis

For analysis, the MRIs were transferred to a multimodality station with a Windows platform system. Endocardial and epicardial borders of the left ventricle were traced with an automatic segmentation method, from which the basic heart shape and functional parameters, such as end-systolic volume (ESV), end-diastolic volume (EDV), stroke volume (SV), left ventricular ejection fraction, and cardiac output, were calculated automatically. ESV, EDV, SV, and cardiac output were standardized as end-systolic volume index (ESVI), end-diastolic volume index (EDVI), stroke volume index (SVI), and cardiac index by body surface area. Long-axis length was measured in 2-chamber view from the apex to the midpoint of the mitral valve and short-axis length was measured on the line that was perpendicular to the long-axis line at the level of the midpoint of the long axis. From the same view, the apical area was measured as the area of blood pool from the short-axis level to apex. The value was calculated automatically by manually tracing endocardial contour through an interactive interface. The apical triangle area was calculated by the length of the long axis and short axis (Figure 1, Figure E1).

Contrast-enhanced images were scored visually using the 17-segment model as recently proposed.[13] Each segment was graded on a 5-point scale (segmental scar score): 0, absence of hyperenhancement; 1, hyperenhancement of 1% to 25% of left ventricular wall thickness; 2, hyperenhancement extending to 26% to 50%; 3, hyperenhancement extending to 51% to 75%; and 4, hyperenhancement extending to 76% to 100%.[14] All imaging parameters were obtained and analyzed blindedly by 2 trained clinical observers separately.

Parameters Calculation

SI, vSI, EI, and ACR were calculated according to formulas 1 through 4, respectively. SI and vSI were unitless indices ranging from 0 for a line, in which short axis = 0, to 1 for a circle, short axis = long axis. On the contrary, EI ranged from 0 for a circle, in which short axis = long axis, to 1 for a line, in which long axis = 0. ACR is an index theoretically always larger than 1. The larger the value, the more deformation of the left ventricular apex.

$$SI = \frac{SA}{LA} \quad \text{(Formula 1)}^{15}$$

$$vSI = \frac{6LVV}{\pi L^3} \quad \text{(Formula 2)}^{16}$$

ET/BS