Left and right ventricular diverticula: Incidence and imaging findings on 256-slice multidetector CT

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Purpose

Cardiac ventricular diverticulum is a rare congenital malformation. The entity is usually asymptomatic but can rarely cause complications and mimic other severe cardiac diseases on imaging. The incidence of congenital left ventricular diverticula was previously reported to be 0.4% in an autopsy series of patients who had died as a result of cardiac disease, 0.076% of over 13,0000 congenital heart operations, 0.26% in a population of nonselected patients referred for cardiac catheterization, or 0.04% in a large retrospective echocardiographic study.

There are few reports of cardiac multidetector CT angiography (MDCTA) findings of ventricular diverticula. Srichai et al reported an incidence of left ventricular diverticula of 2.2% on 64-slice MDCTA. However, there are limited other data, and to our knowledge, there is no report of ventricular diverticula using the most recent generation MDCT scanners. Moreover, the frequency and imaging appearances of right ventricular diverticula on MDCTA are not well documented. In this study, we evaluated incidence and imaging findings of left and right ventricular diverticula in a larger group of patients who underwent ECG-gated cardiac 256-slice MDCTA.
Methods and Materials

Patients

ECG-gated contrast-enhanced cardiac CTA using a 256-slice MDCT scanner was performed in 337 consecutive patients between January 2009 and September 2010 at our institute. Thirteen patients were excluded because the image quality of the cardiac MDCTA was poor due to motion artifact, noise, or inadequate contrast enhancement.

Ultimately, we analyzed 324 patients (188 men [58%], 136 women; mean [± standard deviation] age, 56 ± 15 years; age range, 7-91 years). ECG-gated cardiac MDCTA was performed for assessment of coronary artery disease (168 patients), coronary artery bypass grafts (23 patients), cardiac valves (38 patients), the left atrium and pulmonary venous anatomy before or after an ablation procedure for atrial fibrillation (45 patients), left ventricular wall and function (9 patients), aortic root (18 patients), cardiac or pericardial masses (7 patients), endocarditis (6 patients), congenital heart diseases (5 patients), pericardium (4 patients), and mediastinal lesion adjacent to the heart (1 patient).

ECG-gated cardiac MDCTA

All studies were performed with a 256-slice MDCT scanner (Brilliance iCT, Phillips Healthcare, Cleveland, OH). The imaging parameters included a slice collimation of 2 × 128 × 0.625 mm, gantry rotation time of 270 milliseconds, a tube voltage of 120 kV, effective tube current of 200 to 826 mA, and reconstruction field of view of 250 mm. Contrast-enhanced image acquisition was performed during a single breathhold after the IV injection of 80-100 mL of 350 mg I/mL of nonionic contrast material (iohexol [Omnipaque, GE Healthcare, Milwaukee, WI]) administered followed by a 50 mL saline flush at a rate of 5-6 mL/s via a power injector. Automatic bolus tracking was employed with a region of interest (ROI) placed in the descending aorta. All scans were initiated 7 second after mean ROI contrast reached a pre-set threshold of 150 Hounsfield Units. Unless contraindicated, the MDCTA studies were performed after coronary vasodilation with 0.4 mg sublingual nitroglycerin for evaluation of the coronary arteries. Intravenous administration of 5-15 mg of metoprolol was used in patients with heart rates of 65 beats per minute or more.

The cardiac MDCTA studies were performed using retrospective (n = 177) or prospective (n = 147) ECG-gating. ECG-based tube current modulation was used for the retrospective ECG-gating studies, decreasing tube current during systole and early diastole and maintaining full selected tube current in mid to late diastole. All images were reconstructed with section thickness of 0.8 to 1.5 mm with 50% overlap using an enhanced semi-smooth reconstruction kernel (XCB).
CT images and Data analysis

A single radiologist with 7 years of experience of cardiovascular CTA reviewed the cardiac MDCTA images in 324 patients to search for ventricular diverticula using a workstation (AquariusNet, TeraRecon Inc., San Mateo, CA). The investigator reviewed all axial MDCTA images and used MPR images for confirmation if necessary. Because muscular diverticula may completely compress during systolic phase and not be visible, the investigator searched for ventricular diverticula on diastolic phase (at 70 to 80% of the R-R interval) images in all patients. Then 3 radiologists with 7, 6 and 8 years of experience in cardiovascular CTA confirmed and evaluated CT findings of ventricular diverticula in consensus. Ventricular diverticulum was identified as a protruding structure with a saclike or tubelike shape and narrow orifice from the ventricular lumen. To distinguish diverticula from trabeculations, we defined diverticula using the following criteria: a lesion depth at least half of the compacted myocardial wall thickness in the left ventricular wall and septal wall, or more than 5 mm from the lumen in the right ventricular wall. The incidence of ventricular diverticula was calculated.

The size of the ventricular diverticula was measured in two orthogonal planes on MPR images. We measured lesion depth on the plane parallel to the long axis of the diverticulum. We measured long and short diameters at the widest diameter on orthogonal plane to the long axis of the diverticulum (plane parallel to the orifice). Location of ventricular diverticula was categorized as anterior, inferior, anteroseptal, inferoseptal, anterolateral, inferolateral wall in the left and right ventricles, and in addition, the apical wall in the left ventricle. Contractility of the diverticula was evaluated in the systolic phase (at 40% of R-R interval) images in patients who underwent retrospective ECG-gated studies. The presence of thrombus in cardiac diverticula and other cardiac abnormalities was evaluated on the MDCTA images. In patients with coronary artery disease, we reviewed the reports of extent of stenosis of coronary arteries evaluated using curved planar reformatted images on the ECG-gated MDCTA studies. The degree of coronary stenosis was classified into three categories: mild, #50% stenosis; moderate, 50-70% stenosis; severe, # 70% stenosis. In patients with ventricular diverticulum, the investigator reviewed the medical histories for presence of cardiac diseases, congenital abnormalities, and complications of ventricular diverticula. Continuous variables were described as mean values, whereas categorical variables were described as percentages.
Results

Overall, 18 cardiac ventricular diverticula were detected in 11 patients (3.4%) of 324 patients on ECG-gated cardiac MDCTA. The clinical and MDCTA imaging characteristics of the patients are shown in Fig. 1 on page 6. The patients with ventricular diverticula included 3 men and 8 women between the ages of 18 and 83 years old (mean age, 53 ± 17 years). The patients were referred for several indications including chest pain (3 patients); arrhythmia (4 patients); known cardiac diseases including coronary artery disease (2 patients), endocarditis (1 patient), and anomalous origin of the right coronary artery (RCA) (1 patient). Fifteen diverticula were located in the left ventricle (Fig. 2 on page 6, Fig. 3 on page 7, Fig. 4 on page 8, Fig. 5 on page 9) and 3 in the right ventricle (Fig. 5 on page 9). The incidence of left and right ventricular diverticula was 3.4% and 0.6%, respectively.

The left ventricular diverticula were commonly located in the inferoseptal (n = 8) (Fig. 2 on page 6, Fig. 4 on page 8, Fig. 5 on page 9) and anteroseptal walls (n = 4). The right ventricular diverticula were located in the inferoseptal (n = 2) (Fig. 5 on page 9) and anteroseptal walls (n = 1). A single diverticulum in 6 patients (55%) and multiple diverticula in 5 patients (45%) were detected. All right ventricular diverticula were associated with left ventricular diverticula (Fig. 5 on page 9). When multiple diverticula were present, they were commonly found clustered close to one another (Fig. 2 on page 6, Fig. 5 on page 9). The diverticula ranged from 7 to 16 mm in maximum dimension (mean, 10 ± 3 mm). Each of 13 ventricular diverticula that were imaged with retrospective ECG-gated studies showed synchronous contraction with adjacent myocardium in systolic phase (Fig. 2 on page 6, Fig. 3 on page 7). Four ventricular diverticula were completely closed during systolic phase. No thrombus was found within the diverticula.

In patients with ventricular diverticula, no congenital cardiac abnormality was found other than the patient with anomalous origin of the RCA. Five patients had arrhythmias including atrial fibrillation (n = 4), atrioventricular block (n = 1), Wolff-Parkinson-White syndrome (n = 1). Three patients had mild to moderate coronary artery disease, but no patient had a history of myocardial infarction. No patient had systemic embolization (Fig. 1 on page 6).
### Imaging and clinical characteristics of 18 ventricular diverticula in 11 patients.

<table>
<thead>
<tr>
<th>Case</th>
<th>Age</th>
<th>Gender</th>
<th>Number of diverticula</th>
<th>Ventricle</th>
<th>Location</th>
<th>Size (mm)</th>
<th>Contractility in systole</th>
<th>Other cardiac abnormalities</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>52</td>
<td>M</td>
<td>2</td>
<td>Left</td>
<td>Inferoseptal</td>
<td>9 × 5 × 12</td>
<td>Contracted</td>
<td>AF, AV block</td>
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<td>2</td>
<td>77</td>
<td>F</td>
<td>1</td>
<td>Left</td>
<td>Inferoseptal</td>
<td>13 × 5 × 13</td>
<td>Contracted</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>18</td>
<td>F</td>
<td>2</td>
<td>Left</td>
<td>Apical</td>
<td>8 × 5 × 5</td>
<td>Contracted</td>
<td>AF</td>
</tr>
<tr>
<td>4</td>
<td>54</td>
<td>M</td>
<td>2</td>
<td>Left</td>
<td>Inferoseptal</td>
<td>2 × 2 × 8</td>
<td>Closed</td>
<td>WPW syndrome</td>
</tr>
<tr>
<td>5</td>
<td>54</td>
<td>F</td>
<td>1</td>
<td>Left</td>
<td>Anteroapical</td>
<td>6 × 2 × 9</td>
<td>Contracted</td>
<td>AF</td>
</tr>
<tr>
<td>6</td>
<td>28</td>
<td>F</td>
<td>1</td>
<td>Left</td>
<td>Anteroapical</td>
<td>5 × 2 × 7</td>
<td>Contracted</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>83</td>
<td>F</td>
<td>1</td>
<td>Left</td>
<td>Inferior</td>
<td>5 × 2 × 12</td>
<td>Contracted</td>
<td>CAD (mild)</td>
</tr>
<tr>
<td>8</td>
<td>56</td>
<td>F</td>
<td>1</td>
<td>Left</td>
<td>Inferoseptal</td>
<td>10 × 3 × 8</td>
<td>N/A</td>
<td>Post TVR, endocarditis</td>
</tr>
<tr>
<td>9</td>
<td>51</td>
<td>M</td>
<td>1</td>
<td>Left</td>
<td>Inferoseptal</td>
<td>15 × 6 × 7</td>
<td>AF</td>
<td>N/A</td>
</tr>
<tr>
<td>10</td>
<td>57</td>
<td>F</td>
<td>4</td>
<td>Left</td>
<td>Anteroapical</td>
<td>5 × 2 × 7</td>
<td>N/A</td>
<td>CAD (moderate)</td>
</tr>
<tr>
<td>11</td>
<td>53</td>
<td>F</td>
<td>2</td>
<td>Right</td>
<td>Anteroapical</td>
<td>13 × 3 × 8</td>
<td>Contracted</td>
<td>Anomalous origin of RCA</td>
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<td></td>
<td>Right</td>
<td>Inferoseptal</td>
<td>10 × 2 × 8</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>Right</td>
<td>Anteroapical</td>
<td>4 × 3 × 7</td>
<td>Contracted</td>
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<td>Right</td>
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<td>Closed</td>
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<td>Right</td>
<td>Inferoseptal</td>
<td>7 × 6 × 12</td>
<td>Contracted</td>
<td></td>
</tr>
</tbody>
</table>

1) Data show long diameter x short diameter x depth.
AF: atrial fibrillation
AV: atrioventricular
CAD: coronary artery disease
N/A: not available
RCA: right coronary artery
TVR: tricuspid valve replacement
WPW: Wolff-Parkinson-White

**Fig. 0:** Imaging and clinical characteristics of 18 ventricular diverticula in 11 patients.

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52-year-old man with left ventricular diverticula (case 1). Multiplanar reformatted (MPR) MDCT (vertical long) images in diastolic (a) and systolic (b) phases show two diverticula (arrows) in the inferoseptal wall of the left ventricle. The diverticula show contraction in the systolic phase (b).

**Fig. 0:** 52-year-old man with left ventricular diverticula (case 1). Multiplanar reformatted (MPR) MDCT (vertical long) images in diastolic (a) and systolic (b) phases show two diverticula (arrows) in the inferoseptal wall of the left ventricle. The diverticula show contraction in the systolic phase (b).

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77-year-old woman with a left ventricular diverticulum (case 2). MPR MDCT (horizontal long) images in diastolic (a) and systolic (b) phases show two diverticula (arrow) in the apical wall of the left ventricle. The diverticula show contraction in the systolic phase (b).

**Fig. 0:** 77-year-old woman with a left ventricular diverticulum (case 2). MPR MDCT (horizontal long) images in diastolic (a) and systolic (b) phases show two diverticula (arrow) in the apical wall of the left ventricle. The diverticula show contraction in the systolic phase (b).

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**Fig. 0:** 56-year-old woman with a left ventricular diverticulum (case 8). MPR MDCT (a, horizontal long; b, short axial) images in diastolic phase show a left ventricular diverticulum (arrows) in the inferoseptal wall.

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**Fig. 0:** 53-year-old woman with left and right ventricular diverticula (case 11). MPR MDCT (a-c, horizontal long; d-e, short axial) images in diastolic phase show a left ventricular diverticulum (arrows) and a right ventricular diverticulum (arrowhead) in the inferoseptal wall.
Conclusion

In the current study, the incidence of left and right ventricular diverticula on 256-slice MDCTA was 3.4% and 0.6%, respectively. The incidence is higher than that on autopsy, surgery, cardiac catheterization, and echocardiography in the previous reports. Recognition of this uncommon lesion is important to avoid confusion with other similar-appearing entities and because it may occasional be symptomatic.
References

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