Comparison of Endocardial and Epicardial Lesion Size Following Large-Tip and Extra-Large-Tip Transcatheter Cryoablation

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Background: The efficacy of transcatheter cryoablation for ventricular tachycardia (VT) remains controversial because of the limited size of the lesion produced. An increased lesion size if the cryoablation catheter profile and catheter tip length were increased was hypothesized.

Methods and Results: Closed-chest transcatheter cryoablation was applied with 7F, 6-mm tip (n=11, 7F group) and 9F, 8-mm tip (n=8, 9F group) catheters to the left ventricular (LV) endocardium and epicardium. Catheter-tip temperature was set to −70 to −80°C, and cryoablation duration was set to 240 s. In acute experiments in the 7F group, endocardial lesion volume was 144.1±86.0 mm³ and lesion depth was 5.1±1.6 mm, and epicardial lesion volume was 205.6±157.8 mm³ and lesion depth was 4.7±2.2 mm. In the 9F group, endocardial lesion volume was 301.5±177.4 mm³ (P<0.001 vs 7F group) and lesion depth was 8.4±1.9 mm (P<0.001 vs 7F group), and epicardial lesion volume was 375.3±167.6 mm³ (P<0.01 vs 7F group) and lesion depth was 5.0±2.3 mm.

Conclusions: Transcatheter cryoablation of the LV endocardium and epicardium using a larger profile and longer tip electrode may be useful for treating VT originating from the midmyocardium or epicardium. (Circ J 2009; 73: 1619–1626)

Key Words: Catheter ablation; Cryoablation; Epicardium; Endocardium

Cryoablation has certain advantages over radiofrequency (RF) ablation in the clinical setting.1–7 Cryoablation affords absolute catheter stability during energy delivery and yields sharply demarcated lesions.1 Cryoablation does not produce charring and is less injurious to structures contiguous to the target tissue.2,4 Finally, tissue cooling may produce transient electrophysiologic effects, thus enabling reversible “cryomapping”.3,5–7 Nevertheless, transcatheter endocardial cryoablation is associated with lower acute and chronic success rates for some arrhythmias when compared with RF ablation.8–11 This lower success rate may be a result of the smaller lesion produced by cryoablation.1,8–11 Previous reports indicate that the lesion size is proportional to the cryoablation temperature, probe contact surface area, duration of energy application, and number of freeze–thaw cycles.12–14 Furthermore, focal ventricular tachycardia (VT) or ventricular premature beats (VPBs) arising from epicardial tissue and reentry circuits of the VTs or VPBs associated with structural heart disease resistant to transcatheter endocardial ablation have been shown to be located deep within the midmyocardium or in the epicardium.15 However, no previous study has examined the effect of electrode size and convective warming on lesion size during catheter-based endocardial and epicardial cryoablation. The aim of this study was to compare the effect of electrode diameter and length on the size of the lesion produced by transcatheter ablations of the endocardial and epicardial ventricular myocardium.

Methods

The care of all animals in this study conformed to the American Heart Association’s scientific position on Research Animal Use and was carried out in accordance with accepted guidelines for the care and treatment of experimental animals at Nihon University School of Medicine.

Experimental Animals

We used 10 pigs weighing 30–35 kg and 10 mongrel dogs weighing 15–23 kg for the experiments. The animals were divided into 2 subgroups: 10 pigs and 2 dogs for the acute experiments, and 8 dogs for the chronic experiments.

Surgical Procedure

All animals were premedicated by intramuscular injection of ketamine (20 mg/kg), xylazine (4 mg/kg), and atropine (1 mg). For anesthesia, pentobarbital (30 mg/kg) was given intravenously and pentobarbital (100 mg) was given intravenously as needed. The animals were then intubated and ventilated mechanically with a volume ventilator (Model 613, Harvard Apparatus, South Natick, MA, USA). Intra-
venous Ringer's solution was infused as needed to correct fluid loss.

Access to the Endocardium and Epicardium
The cryocatheters were advanced retrogradely into the left ventricle (LV) through the right carotid artery and/or placed in the pericardial space via transthoracic subxiphoid puncture, as described previously. In brief, the epicardial space was entered via a subxiphoid approach with a 17-gauge Tuohy needle (98.4-mm overall length, 1.5-mm outer diameter; Arrow International Inc, Reading, PA, USA). Under fluoroscopic guidance, small amounts of contrast medium were injected through the needle while it was advanced into the pericardial space. Once this space was entered, a guidewire was passed through the needle, the needle was removed, and an introducer sheath was advanced over the wire. An ablation catheter was then passed through the sheath and maneuvered within the pericardial space to perform epicardial cardiac mapping and ablation.

Selecting Sites for Cryoablation
Cryoenergy was delivered to the endocardial and epicardial surfaces of the heart under fluoroscopic guidance: 4–6 focal lesions were placed at least 30 mm apart (ie, approximately 5 times the length of the shorter cryocatheter tip used in this study).

Cryoablation System
The cryoablation system consisted of 3 major components: the catheter, umbilical connections, and console. Two types of catheters (Cryocath® Technologies Inc, Montreal, Quebec, Canada) were used: one had had a 7F, 6-mm tip (Freezor™ Xtra, 110-cm usable length, quadripolar, unidirectional deflection) and the other had a 9F, 8-mm tip (Freezor™ MAX). An internal thermocouple wire, present in both catheter types, enabled the measurement of catheter tip temperatures cooler than –75°C. The catheter delivered cryoenergy for 4 min using N₂O as the refrigerant, resulting in an average catheter-tip temperature of –82±5°C.

Acute Experiments
The 7F, 6-mm tip catheter was used to perform LV endocardial and epicardial cryoablation in 7 pigs and 1 dog. The 9F, 8-mm tip catheter was used to perform LV endocardial and epicardial cryoablation in 3 pigs and 1 dog.

Chronic Experiments
The 7F, 6-mm tip catheter was used to perform LV endocardial and epicardial cryoablation in 4 dogs. The 9F, 8-mm tip catheter was used to perform LV endocardial and epicardial cryoablation in 3 dogs and LV epicardial cryoablation in 1 dog.

Effects of Epicardial Arteries and Fat on Lesion Size
In 5 pigs, the heart was exposed via median sternotomy and suspended in a pericardial cradle. Cryoenergy was applied with the 7F, 6-mm tip catheter to the left anterior descending coronary artery (LAD) (n=8 applications), the diagonal branch of the LAD (n=3 applications), and epicardial fat >2 mm in thickness (n=5 applications).

Histological Analysis
In the acute and epicardial artery/fat experiments, animals were killed 1 h after the last cryoablation. Cryolesions were identified upon gross examination by the presence of reddish pink areas surrounded by small hemorrhagic lesions. In the chronic experiments, animals were killed 4–6 weeks after cryoablation. Cryolesions were identified upon gross examination by the presence of well-demarcated fibrous scars.

Lesions on the endocardial and epicardial surfaces were measured with a surgical ruler to quantify the depth and length along the short and long axes. Tissue sections from grossly detectable cryolesions were fixed in 10% formalin, subsequently dehydrated, embedded in paraffin, sectioned at 5-μm thickness, and stained with H&E for the acute experiments, and otherwise with H&E and Masson's trichrome stains. Lesion volumes were calculated as 1/6π×maximum depth×maximum width×maximum length. This equation describes half the volume of a hemi-rotated ellipsoid.

Statistical Analysis
Values are expressed as mean±SD. Differences in continuous variables were analyzed by unpaired Student’s t-test. A P-value of less than 0.05 was considered statistically significant. StatView 5.0 software (SAS Institute, Cary, NC, USA) was used for data analysis.

The authors had full access to the data and take responsibility for its integrity. All authors have read and agree with the manuscript as written.

Results

Lesion Sizes

Acute Experiments
For LV endocardial cryoablation, 35 lesions were attempted with the 7F, 6-mm tip catheter, and 8 lesions were attempted with the 9F, 8-mm tip catheter (Figure 1). LV endocardial lesion depth was 5.1±1.6 mm with the 7F, 6-mm tip catheter and 8.4±1.9 mm with the 9F, 8-mm tip catheter (P<0.001 vs 7F catheter) (Figure 2). LV endocardial volume was 144.1±86.0 mm³ with the 7F, 6-mm tip catheter and 301.5±177.4 mm³ with the 9F, 8-mm tip catheter (P<0.001 vs 7F catheter) (Figure 2).

For LV epicardial cryoablation, 25 lesions were attempted with the 7F, 6-mm tip catheter, and 11 lesions were attempted with the 9F, 8-mm tip catheter (Figure 1). LV epicardial lesion depth was 4.7±2.2 mm with the 7F, 6-mm tip catheter and 5.0±2.3 mm with the 9F, 8-mm tip catheter (no statistical significance vs 7F catheter) (Figure 2). LV epicardial volume was 205.6±157.8 mm³ with the 7F, 6-mm tip catheter and 375.3±167.6 mm³ with the 9F, 8-mm tip catheter (P<0.01 vs 7F catheter) (Figure 2).

Chronic Experiments
For LV endocardial cryoablation, 18 lesions were attempted with the 7F, 6-mm tip catheter, and 17 lesions were attempted with the 9F, 8-mm tip catheter (Figures 3A, 4). LV endocardial lesion depth was 4.8±1.4 mm with the 7F, 6-mm tip catheter and 6.3±0.9 mm with the 9F, 8-mm tip catheter (P<0.001 vs 7F catheter) (Figure 4). LV endocardial volume was 182.6±71.7 mm³ with the 7F, 6-mm tip catheter and 266.9±99.1 mm³ with the 9F, 8-mm tip catheter (P<0.01 vs 7F catheter) (Figure 4).

For LV epicardial cryoablation, 12 lesions were attempted with the 7F, 6-mm tip catheter, and 9 lesions were attempted with the 9F, 8-mm tip catheter (Figures 4, 5). LV epicardial lesion depth was 3.3±0.3 mm with the 7F, 6-mm tip catheter and 4.1±0.9 mm with the 9F, 8-mm tip catheter (P<0.01 vs 7F catheter) (Figure 3B). LV epicardial volume was 200.2±42.7 mm³ with the 7F, 6-mm tip catheter and 296.9±72.2 mm³ with the 9F, 8-mm tip catheter (P<0.01 vs 7F catheter) (Figure 4).
Figure 1. Gross images of left ventricular myocardium after cryoablation in acute experiments. (Upper) Endocardial cryolesions produced with the 7F, 6-mm tip catheter (A) and the 9F, 8-mm tip catheter (B). (Lower) Epicardial cryolesions produced with the 7F, 6-mm tip catheter (C) and 9F, 8-mm tip catheter (D).

Figure 2. Left ventricular lesion depth and volume produced by cryoablation in acute experiments. (Upper) Endocardial cryolesion depth and volume produced with the 7F, 6-mm tip and 9F, 8-mm tip catheters. (Lower) Epicardial cryolesion depth and volume produced with the 7F, 6-mm tip and 9F, 8-mm tip catheters. NS, not significant.
Lesion Sizes on the Epicardial Arteries and Fat
LV epicardial lesion depths and volumes were 1.0±1.6 mm and 38.8±22.1 mm³ on the LAD, 5.2±2.1 mm and 207.9±229.5 mm³ on the diagonal branch of the LAD, and 2.7±1.0 mm and 86.3±37.5 mm³ on the fat, respectively (Figures 5A–C, 6). No infarcts at sites supplied by the targeted vessels were observed upon gross analysis. In the chronic experiment with the 9F, 8-mm tip catheter, an epicardial lesion was noted around the diagonal branch, and no lesion was noted beneath the diagonal branch in 1 dog (Figure 5D).

Evaluation of Lungs
The mediastinal and pleural cavities were explored in each animal. A total of 2 cryolesions were identified in underlying lung tissue in dogs that underwent cryoablation with the 9F, 8-mm tip catheter. An example of a lung lesion is shown in Figure 7.

Discussion
Transcatheter cryoablation has been used to cure atrioventricular nodal reentrant tachycardia (AVNRT) without the complication of atrioventricular block. However, cryoablation is reported to have higher primary failure (15.4% with cryoablation vs 2.8% with RF ablation) and recurrence rates compared with RF ablation for AVNRT (19.8% with cryoablation vs 5.6% with RF ablation). Furthermore, a recent study showed that the AVNRT recurrence rate was higher with a 4-mm tip cryoablation catheter (18%) than with a 6-mm tip cryoablation catheter (9%). Thus, in the present study we compared the effect of cryoablation catheter size and length on acute and chronic left ventricular lesion sizes. We evaluated cryocatheters of 2 different sizes in porcine and canine endocardial and epicardial ablation models, and examined the acute and chronic effects of cryothermal ablation on ventricular tissue. Each cryoablation lesion consisted of sharply demarcated coagulation necrosis that was free of interspersed viable myocardium.
Endo- and Epicardial Transcatheter Cryoablation

Figure 4. Left ventricular lesion depth and volume produced by cryoablation in chronic experiments. (Upper) Endocardial cryolesion depth and volume produced with the 7F, 6-mm tip and 9F, 8-mm tip catheters. (Lower) Epicardial cryolesion depth and volume produced with the 7F, 6-mm tip and 9F, 8-mm tip catheters.

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<td>9F, 8 mm (N=17)</td>
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<td>300</td>
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<tr>
<th></th>
<th>Epicardium</th>
<th>Volume</th>
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<tr>
<td>Depth</td>
<td>P&lt;0.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(mm)</td>
<td>(mm³)</td>
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<tr>
<td>9F, 8 mm (N=9)</td>
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Figure 5. Gross and microscopic images obtained after epicardial cryoablation in the vicinity of the coronary arteries by the 7F, 6-mm tip catheter. (A) Cryolesion produced on the LAD in the open-chest acute experiment. (B) Microscopic features of the specimen shown in (A). Note the preservation of the muscle directly underneath the LAD. The LAD was spared from the effects of the cryolesion, and there is no endothelial disruption. (C) Cryolesion produced on the diagonal branch of the LAD in the open-chest acute experiment. (D) Cryolesion produced in the vicinity of the diagonal branch in the closed-chest chronic experiment.
We made the following observations. Endocardial lesion depth and volume were larger with the 9F, 8-mm tip catheter than with the 7F, 6-mm tip catheter in both the acute and chronic experiments. Epicardial lesion depths were similar between the 7F, 6-mm and 9F, 8-mm catheters, but epicardial lesion volumes were larger with the 9F, 8-mm tip catheter compared with that with the 7F, 6-mm catheter in the acute experiments. Epicardial lesions produced with 7F, 6-mm catheter in the chronic experiments were shallower than those in the acute experiments (3.3±0.3 mm vs 4.7±2.2 mm, \( P<0.05 \)), but epicardial lesion depth with the 9F, 8-mm catheter was similar between the acute and chronic experiments (5.0±2.3 mm vs 4.1±0.9 mm, no statistical difference). The shallower epicardial lesion produced by the 7F, 6-mm tip catheter rather than the 9F, 8-mm tip catheter in the chronic experiments might be explained by the lesser lesion length and width created by the 7F, 6-mm tip catheter in the acute phase. The lesser lesion volume at similar lesion depths between the 7F, 6-mm tip and 9F, 8-mm tip catheter probably made recovery from cryoablation injury possible during the subacute phase. Epicardial lesions were smaller in depth and volume in the presence of epicardial blood vessels and fat and were markedly smaller near larger vessels than near smaller vessels.

**Comparison of Present Study Results With Previous Reports of Catheter Cryoablation (Table)**

In 1998, Dubuc et al first showed the feasibility of transcatheter cryoablation in the ventricle with a 9F, 4-mm tip electrode using Halocarbon 502 (Freon®) as the refrigerant. They achieved a nadir temperature of \(-45±9.8^\circ\text{C}\) for 1–4 min and created lesions with a mean length of 5.0±1.9 mm, width of 3.6±1.5 mm, depth of 3.5±1.9 mm, and volume of

**Table. Catheter-Based Cryoablation and Lesion Characteristics**

<table>
<thead>
<tr>
<th></th>
<th>Dubuc (^{20})</th>
<th>Wadhwa (^{21})</th>
<th>Reek (^{22})</th>
<th>Lustgarten (^{23})</th>
<th>d’Avila (^{25})</th>
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<tr>
<td>Temperature (°C)</td>
<td>–45±9.8</td>
<td>–79.6±4.9</td>
<td>–84.1±0.9</td>
<td>–82±5</td>
<td>–77±2</td>
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<td>Cooling time (min)</td>
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<td>4.8±2.4</td>
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<td>Catheter size</td>
<td>9F/4 mm</td>
<td>10F/6 mm</td>
<td>10F/6.5 mm</td>
<td>7F/6 mm</td>
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<td>Endocardial lesion depth (mm)</td>
<td>3.6±1.9</td>
<td>10.0±4.9</td>
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<td>4.8±0.2</td>
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<tr>
<td>Endocardial lesion volume (mm(^3))</td>
<td>45.4±62.6</td>
<td>1,207±1,158</td>
<td>262±166</td>
<td>NA</td>
<td>NA</td>
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<tr>
<td>Epicardial lesion depth (mm)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>1.6±0.7</td>
<td>4.6±0.9</td>
</tr>
<tr>
<td>Epicardial lesion volume (mm(^3))</td>
<td>NA</td>
<td>NA</td>
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45.4±62.6 mm². In 2000, Wadhwa et al reported transcatheter cryoablation in the ventricle with a 10F, 6-mm tip electrode using N₂O gas as the refrigerant. They achieved a nadir temperature of –79.6±4.9°C, and a mean freeze duration of 4.8±2.4 min, and they created a lesion with a mean width of 4.8±2.4 mm, depth of 10.0±4.9 mm, and volume of 1.207±1.158 mm³. Reek et al reported on catheter cryoablation in normal ventricular myocardium and healed myocardial infarction in a sheep model. Cryoablation in healthy LV with a 10F, 6.5-mm tip electrode and N₂O gas used as the refrigerant resulted in a nadir temperature of –84.1±0.9°C, total freeze duration of 5 min, and lesion volume of 262±166 mm³. The lesion volume in myocardial tissue subjected to chronic infarction was 501±424 mm³ after a mean 6±3 applications of 2 freeze–thaw cycles (2±3 min). Lustgarten et al reported epicardial cryoablation in a canine model using 2 types of 7F catheters: a 6-mm or 3-cm linear freezing element. Cryoablation at an average temperature of –82±5°C for 4 min with the 6-mm tip produced lesions with a mean epicardial length of 8.7±6.8 mm, width of 6.7±6.8 mm, and depth of 1.6±0.7 mm, and that with the 3-cm linear tip produced lesions with a mean length of 35.7 mm, width of 8.1 mm, and depth of 2.7 mm, as measured 4–6 weeks after cryoablation. Wood et al performed in-vitro experiments with 7F, 4-mm and 9F, 8-mm tip catheters and found that cryoablation lesion sizes and tissue temperatures are related to convective warming, electrode orientation, electrode contact pressure, and any of the following: electrode size, catheter tip freezegate, and electrode temperature. d’Avila et al reported that endocardial and epicardial cryolesions created in a normal caprine model by focal cryoablation for 4 min with a 7F, 6-mm tip catheter at a mean temperature of –77±2°C for endocardium and –81±3°C for epicardium were similar in size and depth (endocardium: 9.7±0.4 mm long, 7.3±1.4 mm wide, 4.8±0.2 mm deep; epicardium: 10.2±1.4 mm long, 7.7±2.0 mm wide, 4.6±0.9 mm deep). They also reported that the epicardial cryolesion created in a porcine chronic infarct model by linear cryoablation with a 7F, 30-mm tip catheter at a mean temperature of –84±6°C for 4 min was 36.5±7.8 mm long, 8.2±1.3 mm wide, and 6.0±1.2 mm deep. Herein, we report for the first time the effects of the size of catheter used in the acute and chronic phases on the size of lesions created by transcatheter ablation of endocardial and epicardial myocardium. The endocardial lesion depth with 7F, 6-mm tip in our experiments was similar to that reported by d’Avila et al using the same type of electrode (5.1±1.6 mm vs 4.8±0.2 mm), and endocardial lesion depth with a 9F, 8-mm tip electrode in our experiments was similar to that reported by Wadhwa et al using a 10F, 6-mm tip electrode (8.4±1.9 mm vs 10.0±4.9 mm). The epicardial lesion depth in our experiments with a 7F, 6-mm tip electrode was similar to that reported by d’Avila et al using the same type of electrode (4.7±2.2 mm vs 4.6±0.9 mm). However, there are no previous reports on the epicardial lesion depth and volume using a 9F, 8-mm tip electrode. Our data indicate that the larger catheter tip resulted in a larger lesion in both the endocardial and epicardial myocardium, and that epicardial lesions were larger than endocardial lesions in both acute and chronic experiments because of the absence of blood flow within the pericardial space. Furthermore, large epicardial vessels and fat markedly reduced the lesion size.

Comparison Between Cryothermia and RF Ablation Lesions
Cryoenergy is believed to result in less endothelial and cellular disruption than RF energy; it is often assumed, therefore, that lesions created by cryothermia are smaller than those created by RF. The results of the present study indicate, however, that focal epicardial cryolesions created in normal animals are similar to or larger than those created by standard RF energy. This finding is supported by previous reports that epicardial lesions created with a standard 4-mm tip RF ablation catheter resulted in lesions 14.9±2.7 mm in length, 11±2.7 mm in width, and 3.7±1.3 mm in depth in an acute study, and lesions 7.7±2.8 mm in length, 6.5±1.6 mm in width, and 2.67±0.35 mm in depth in a chronic study. However, the use of a cooled-tip RF catheter resulted in larger epicardial lesions 15.9±3.5 mm in length, 13.7±3.5 mm in width, and 6.7±1.7 mm in depth in the same acute study.

Effect on Epicardial Vessels and Fat
Acute occlusion of epicardial blood flow was possible during application of cryothermal energy, but the effect was acutely reversible following thawing in all animals. Iida et al showed acute occlusion using a 5-mm cryoprobe delivering –60°C directly to epicardial vessels in an open chest canine model. Histology was evaluated at 4 days, and at 1, 2, 4, 8, and 16 weeks. Evidence of medial and intimal damage was present, with up to 20–50% stenosis observed at 1 month. However, less intimal damage observed by Holman et al at 6 months, suggesting possible regression over time. Cryoapplication increases collagen I and III expression in the vessel wall; therefore, the negative vascular remodeling by cryoapplication appears to be related to extracellular matrix modulation. There was no evidence to suggest that acute occlusion of flow resulted from acute thrombosis, because no myocardial infarct was observed in any of the animals, and any acute ischemic changes that may have occurred were reversed upon thawing. No evidence of microscopic injury was found in animals that received cryolesions on the LAD or diagonal branch in the acute study. However, light neointimal proliferation was observed in the diagonal branch in 1 chronic model. In a previous study, neointimal proliferation was observed in 13 epicardial vessels, with no evidence of damage in vessels with internal diameters greater than 0.7 mm, and occlusive injury was identified in 1 small vessel branch. In another study of epicardial cryoablation in 2 normal goats, 2 cryolesions were found in the vicinity of a marginal branch of the circumflex coronary artery and a small branch of the LAD, and autopsy revealed neither endothelial disruption nor intravascular thrombi in these vessels. However, RF epicardial ablation with a 7F, 4-mm tip electrode applied at 0.15±0.08 mm from vessels with internal diameters of 0.78±0.49 mm resulted in severe intimal hyperplasia or intravascular thrombosis. RF epicardial ablation with a 7F, 4-mm cooled-tip electrode on vessels with an internal diameter ≤0.24±0.15 mm resulted in severe hyperplasia and/or endovascular thrombosis, and vessels with an internal diameter of 0.51±0.3 mm showed matrix proliferation in the media, but no endothelial disruption, neointimal proliferation, or intravascular thrombosis. Another study showed that cooled-tip RF ablation is safe if the ablation sites are located 5 mm from the major coronary arteries, but the LAD was injured in 4 of 7 ablation lesions created above or within 5 mm of the LAD. Thus, cryoablation might be safer than...
RF ablation with regard to epicardial vessel damage in patients with VT of epicardial origin or in minimally invasive cardiothoracic surgery for atrial fibrillation.32

Study Limitations
In the acute study, we used both dogs and pigs, and the data were combined, whereas in the chronic experiments we used only dogs. Thus, direct comparison of the lesion depth and volume between endocardial and epicardial lesions has some limitations. Epicardial lesions created from freezing of the shaft immediately proximal to the freezing element led to unpredictable extension of lesion length. Although we do not have data regarding how cold the catheter becomes immediately proximal to the element, the lesions observed showed that the temperature is sufficiently low to cause irreversible tissue damage. Therefore, the catheter shaft must be insulated proximal to the freezing element to be clinically useful.

Conclusions
Lesion sizes during catheter cryoablation are maximized by the use of large catheters with large electrodes. Cryoenergy can produce acute and chronic ablation lesions in the LV endocardial and epicardial myocardium. Endocardial and epicardial cryolesions created with a cryoablation catheter are similar in both size and depth. Cryoablation does not appear to damage the coronary arteries.

Disclosures
The authors have no conflicts of interest to disclose.

References