Epicardial linear electroporation ablation and lesion size

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BACKGROUND Electroporation can be used as a nonthermal method to ablate myocardial tissue. However, like with all electrical ablation methods, determination of the energy supplied into the myocardium enhances the clinically required controllability over lesion creation.

OBJECTIVE To investigate the relationship between the magnitude of epicardial electroporation ablation and the lesion size using an electrically isolating linear suction device.

METHODS In 5 pigs (60–75 kg), the pericardium was opened after medial sternotomy. A custom linear suction device with a single 35 × 6–mm electrode inside a 42-mm-long and 7-mm-wide plastic suction cup was used for electroporation ablation. Single cathodal applications of 30, 100, or 300 J were delivered randomly at 3 different epicardial left ventricular sites. Coronary angiography was performed before ablation, immediately after ablation, and after 3 months survival. Lesion size was measured histologically after euthanization.

RESULTS The mean depth of 30, 100, and 300 J lesions was 3.2 ± 0.7, 6.3 ± 1.8, and 8.0 ± 1.5 mm, respectively ($P = .0003$). The mean width of 30, 100, and 300 J lesions was 10.1 ± 0.8, 15.1 ± 1.5, and 17.1 ± 1.3 mm, respectively ($P < .0001$). Significant tissue shrinkage was observed at the higher energy levels. No luminal arterial narrowing was observed after 3 months: 2.3 ± 0.3 mm vs 2.3 ± 0.4 mm ($P = .85$).

CONCLUSION The relationship between the amount of electroporation energy delivered through a linear suction device with a single linear electrode and the mean myocardial lesion size is significant in the absence of major adverse events or permanent damage to the coronary arteries.

KEYWORDS Ablation; Epicardium; Coronary artery; Irreversible electroporation; Safety

ABBREVIATIONS **AF** = atrial fibrillation; **LAD** = left anterior descending

Introduction

Cell membranes can be permanently damaged by a high electric gradient. This may lead to increased permeability, loss of cellular proteins, and eventually necrosis.[1] In the 1980s, the principle of direct current catheter ablation was based on this effect.[2] However, direct current catheter ablation caused electrolysis at the electrode surface that led to a gas bubble, arcing, explosion, and a pressure wave.[2–5] Therefore, when radiofrequency catheter ablation was introduced to cardiac electrophysiology in 1987, it soon became the standard treatment method for cardiac arrhythmias.[6] Unfortunately, radiofrequency energy can cause severe complications such as steam pops or blood coagulation. It can also cause permanent damage to blood vessels and nerves as well as constriction of (pulmonary) veins owing to induction of heat damage to all tissue types near the ablation site.[7–9] Recently, circular electroporation ablation was introduced as a new endocardial catheter ablation energy modality for the treatment of atrial fibrillation (AF).[10] Electroporation ablation also uses a high current density to create myocardial lesions. Its main difference with the technique used in the 1980s is the lower current density at the electrode surface, which prevents the cascade of adverse events. Lavee et al[11] demonstrated the feasibility and safety of epicardial nonthermal electroporation ablation of myocardial tissue. du Pre et al[12] showed that linear epicardial electroporation ablation can create myocardial lesions safely and effectively.

Linear epicardial electroporation ablation could be an effective and fast ablation modality for the (video-assisted) thoracosurgical treatment of atrial arrhythmias and for the treatment of epicardial ventricular arrhythmias.

The purpose of the present porcine study was to investigate the relationship between the magnitude of a linear epicardial electroporation application and the lesion size.

Methods

All studies were approved by the Animal Experiments Committee of the University Medical Center Utrecht,

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Utrecht, The Netherlands, and were performed in compliance with the *Guide for the Care and Use of Laboratory Animals*.[13]

Study protocol

The study was performed in 5 pigs (weight 60–75 kg). Carbasalate calcium (80 mg daily) and clopidogrel (75 mg daily) were given 3 days before the procedure and continued until euthanasia. Amiodarone was given 1 week before the procedure (600 mg daily) to prevent procedure-related ventricular arrhythmias. The animals were sedated, intubated, and anesthetized according to standard procedures.

Linear ablation

The thorax was opened via a medial sternotomy. After angiography of the left anterior descending (LAD) and circumflex coronary arteries via a catheter in the right carotid artery, an approximately 10-cm-long incision was made in the pericardial sack. Epicardial ablation was performed with a custom linear suction device, comprising a 35-mm-long and 6-mm-wide linear electrode inside a 42-mm-long and 7-mm-wide plastic suction cup (Figure 1). The suction device was sucked with a constant under pressure of 50–60 cm H_2O on a position parallel to LAD coronary artery on the left ventricle, on the basal anterolateral part of the left ventricle, or on the apicolateral part of the left ventricle (Figure 2). The constant under pressure should ensure a good electrode-to-myocardium contact in the absence of blood.

A single, 6-ms cathodal application was then delivered. The energy was generated with a monophasic external defibrillator (Lifepak 9, Physio-Control, Inc, Redmond, WA). A large skin patch (7506, Valleylab Inc, Boulder, CO) on the lower back served as an indifferent electrode. The ablation procedure was repeated at 2 other left ventricular epicardial locations, as described above. In each animal, 30, 100, and 300 J were delivered in a random sequence. Voltage and current waveforms of all applications were recorded as described previously.[10] With the suction device still in position after the application, both ends of the device were marked with sutures. Coronary angiography was repeated after the last application.

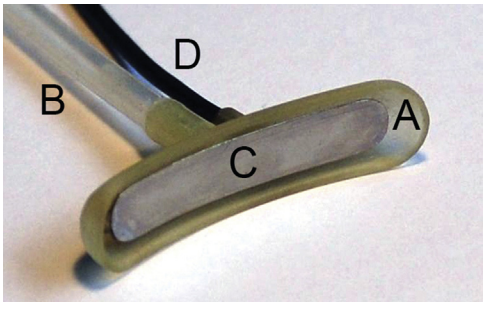

Figure 1 Linear suction device consisting of a 42-mm-long and 7-mm-wide plastic suction cup (**A**) connected to a vacuum system by a tube (**B**) and containing a single 35-mm-long and 6-mm-wide protruding linear electrode (**C**), which is connected by a cable (**D**) to the pulse generator.

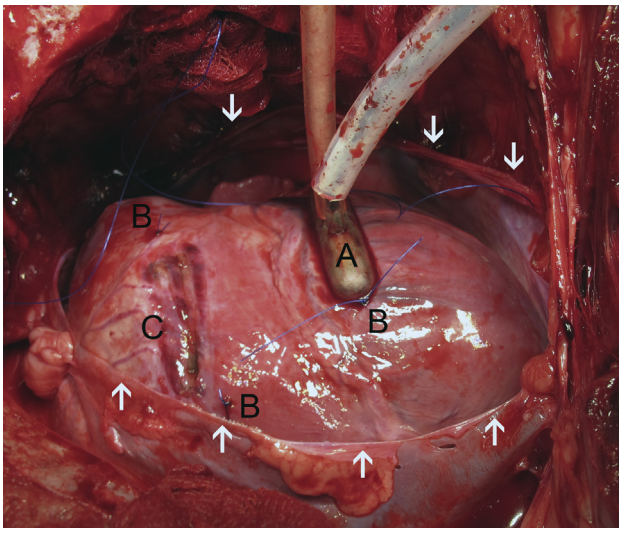

Figure 2 Linear suction device (**A**) is sucked on the epicardium. Around the suction device, a narrow zone of hematoma can be seen. The location of ablation is marked with stitches (**B**) at both far ends of the suction cup. A linear hematoma (**C**) from a previous ablation procedure can be identified. The arrows indicate the pericardium.

After a 3-month survival period, coronary angiography of the LAD and circumflex coronary arteries was repeated, the thorax was opened by sternotomy, and the animal was euthanized by exsanguination. The heart was removed; the pericardium was peeled off; and the areas with ablation lesions were excised, pinned to a flat support, and fixated in formalin.

Coronary angiography

Luminal diameters of the coronary artery proximal and distal to the lesion site and the minimal luminal diameter at the lesion site were measured by using quantitative coronary angiography.

Histological evaluation

After fixation, multiple (range 10–17) 3–4-mm-thick segments of each lesion were taken perpendicular to the linear lesion and to the epicardial surface. Paraffin-embedded segments were sectioned and stained with hematoxylin and eosin and with elastic van Gieson. All sections were scanned and digitized to measure lesion depth and width.

Measurement of lesion size

Lesion depth and width were measured in each histological section. Large lesions often showed tissue shrinkage, as was also seen after myocardial infarction.[14] When sufficient undamaged myocardium was present in the histological section, the estimated original epicardial contour was used to measure lesion depth.[15] From these data, the median depth and width of each lesion were calculated. Subsequently, the mean depth and width of all lesions created with the same energy setting were calculated.