Computerized Three-Dimensional Potential Mapping with a Multielectrode Basket Catheter Can be Useful for Pulmonary Vein Electrical Disconnection*

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Abstract. Introduction: Pulmonary vein (PV) isolation (PVI) has been recently proposed as an effective technique to cure atrial fibrillation (AF).

Aims of the Study: The aim of this study was to investigate the efficacy of a novel technique utilizing a computerized three-dimensional mapping system (QMS2TM) with a multielectrode basket catheter (MBC) for PVI and to reveal the relation between the style of breakthrough and the network of the PV musculature.

Methods: Sixty-five consecutive patients with frequent AF attacks underwent PV mapping with a 31-mm MBC, and a three-dimensional color animation of the potential map was constructed by the QMS2TM. The animation color schema was arranged to minimize the low-amplitude left atrial (LA) potentials and emphasize the high-amplitude PV potentials (PVPs). The longitudinal PVP map enabled us to recognize the true breakthroughs and reveal the network of the PV musculature.

Results: A total of 205 PVs (65 left superior PVs, 65 right superior PVs, 57 left inferior PVs and 18 right inferior PVs) were mapped and successful PVI was achieved in all PVs, except one that had no PVPs, with a mean radiofrequency duration of 7 ± 5 minutes per PV. In about 90% of the PVs, a final radiofrequency application eliminated all the distal PVPs simultaneously because the PVI was performed at the appropriate LA-PV junction. A single segmental breakthrough was detected in 17 PVs, single broad breakthrough in 83 PVs, multiple separate breakthroughs with a distal connection between the PV musculatures extending from each separate breakthrough in 88 PVs and multiple separate breakthroughs without that connection in 16 PVs. During the follow-up period, fifty-one (78%) patients were free of symptomatic AF without any antiarrhythmic drugs after multiple procedures (thirty-three (51%) of those patients after the first procedure) and no PV stenosis was found.

Conclusions: Computerized three-dimensional potential mapping can be useful for PVI because it can not only identify the true breakthrough, but can also confirm the elimination of the breakthroughs by the change in the activation sequence through the network of the PV musculature.

Key Words. atrial fibrillation, pulmonary veins, multielectrode basket catheter, three-dimensional potential mapping, radiofrequency catheter ablation

Introduction

Pulmonary vein (PV) electrical disconnection guided by circumferential mapping with a ring catheter has been recently proposed as an effective technique to cure paroxysmal atrial fibrillation (AF) [1,2]. However, this mapping technique covers only a circumferential area and longitudinal mapping with an ablation catheter needs to be added to identify a true breakthrough. Therefore, appropriate PV isolation (PVI) largely depends on the ablator’s skill. In addition to this technical

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problem, the anatomy and histology of the PVs is complex enough to make the PV mapping more difficult [3,4]. An inappropriate PVI may leave AF foci on the left atrial (LA) side or increase the risk of PV stenosis [5,6]. Sanchez et al. reported the efficacy of longitudinal mapping with a multielectrode basket catheter (MBC) for PVI [7]. Though their mapping technique was very useful, it could not resolve some problems associated with the mapping resolution and identification of the true LA-PV junction. We designed a novel PVI technique utilizing a computerized three-dimensional (3-D) mapping system (QMS2™) with an MBC to overcome all these problems stated above. The aim of this study was to investigate the efficacy of our technique in the treatment of AF and to reveal the style of breakthrough, distribution of the PV musculature and activation pattern within the PVs with the use of a 3-D potential map.

**Methods**

**Patient Characteristics**

The study population consisted of 65 consecutive patients (56 men, 57 ± 12 years) with symptomatic paroxysmal AF refractory to 4 ± 1 class I or class III antiarrhythmic drugs. The mean PAF history was 5 ± 4 years (1 to 15). The mean LA dimension was 36 ± 5 mm (25 to 46) and mean left ventricular ejection fraction 66 ± 9% (47 to 89). One patient had a history of an old myocardial infarction and five had emboli. Each patient gave informed consent, and all antiarrhythmic drugs were discontinued for at least five half-lives prior to the study.

**Electrophysiological Study**

The transseptal procedure was performed with the intracardiac echocardiography guidance recorded with a 9-French transducer catheter (Boston Scientific, Natick, MA, USA) operating at 9 MHz. Catheterization into the LA was performed with a one puncture and two-sheath technique (one sheath (8-French, St. Jude Medical, Daig Division) for an ablation catheter and another (8.5-French, Soft Tip EP Sheath™, EP Technologies) for a mapping catheter). Intravenous heparin was administered to maintain an activated clotting time >250 seconds after the atrial transseptal procedure. The diameters of all four PVs were determined by selective angiography in all cases.

**Target PVs for Isolation and PV Mapping with an MBC**

The left superior PV (LSPV), left inferior PV (LIPV) and right superior PV (RSPV) were all targeted for a novel PVI technique according to the evidence reported in the previous studies [2,8]. Because the right inferior PV (RIPV) is often as difficult to cannulate with an MBC as with a ring catheter, it was not routinely isolated. However, if feasible, the RIPV was also isolated by the same technique as the three other PVs. A 31-mm MBC (Constellation™, EP Technologies) which consisted of eight splines (A–H) with eight 1-mm electrodes with 2-mm spacing, was deployed within the target PV coaxially to its long axis and with its most proximal electrodes positioned at the PV ostium. The location of the MBC splines was determined by bi-plane fluoroscopy on the basis of the position of splines A and B, which could be identified by their radiopaque markers.

**QMS Mapping**

QMS2™ is a computerized 3-D mapping system which can construct a 3-D color map from a total of 56 bipolar electrograms recorded by an MBC [9,10]. The QMS2™ was connected to an MBC via an amplifier. The electrical signals were filtered from 30 to 200 Hz. QMS recordings were obtained during sinus rhythm (right PVs) or distal coronary sinus pacing (left PVs). The time phase of interest was set as the time interval between the earliest atrial potentials and latest PV potentials (PVPs) during one beat. The electrical activity in the space between the splines was estimated by a Bicubic-Spline interpolation to construct a continuous map. A Bicubic-Spline interpolation uses a piecewise polynomial approximation which is made by dividing the interval or space between the signals into a collection of subintervals or subspaces and constructing different approximated cubic polynomials on each subinterval or subspace. An animation of a 3-D potential map, which could reflect a series of electrical activations, was used to reveal the style of breakthrough, distribution of the PV musculature and activation pattern within the PV. The average of the sum of all the amplitudes of the potentials during a 10 msec interval was calculated and expressed on the map in order to exclude the effect of electrical noise. A color setup with a gradation which corresponded to the relative size of the potential amplitude could be arranged variously on the QMS map. For example, in the detection of an AF focus, the color set up needed to be arranged in order to emphasize the small PVPs triggering the AF [9]. In contrast, in the present study, it was essential to minimize the low-amplitude LA potentials and emphasize the high-amplitude PVPs to construct a clear 3-D map of the PVPs. In principle, the color setup was arranged to assign colors consisting of dark green, yellow and red to the potentials with amplitudes larger than half of the largest amplitude of all the related potentials (color threshold). When the small potentials needed to be emphasized, the color threshold was decreased to