Novel method of signal analysis for ablation of Wolff-Parkinson-White syndrome

Scott R. Ceresnak, MD,* Gregory J. Gates, PhD,* Lynn Nappo, RN,* Hillel W. Cohen, DrPH, MPH,† Robert H. Pass, MD*

*From *The Pediatric Arrhythmia Service, Division of Pediatric Cardiology, Department of Pediatrics, The Children's Hospital at Montefiore, Albert Einstein College of Medicine, Bronx, New York and †Department of Epidemiology and Population Health, Albert Einstein College of Medicine, Bronx, New York.*

BACKGROUND Identification of the site of successful radiofrequency catheter ablation (RFCA) for Wolff-Parkinson-White (WPW) syndrome may be subjective.

OBJECTIVE The purpose of this study was to develop an automated signal analysis program to predict a successful ablation site.

METHODS Patients who underwent successful RFCA for WPW from 2008– 2010 at our center were analyzed. Inclusion criteria were age <21 years, loss of preexcitation in <5 seconds, and sustained success at 3 months. Exclusion criteria were congenital heart disease and pacing during RFCA. The standard recording system signal was filtered into low frequency (LF 0–≤0.02 Hz) and high frequency (HF >0.02–≤0.45 Hz). Software identified the beginning of the HF signal, LF and R-wave peaks, LF/HF signal amplitude, and area under the HF/LF signals. Successful and unsuccessful (radiofrequency energy applied without accessory pathway block) signals were compared.

RESULTS Thirty patients were analyzed; 16 had both successful and unsuccessful signals, and 14 had a successful ablation with 1 radiofrequency application. Mean age was 13.7 ± 3.1 years, weight 54.9 ± 22.4 kg, and time to accessory pathway ablation 1.7 ± 1.4 seconds. Significant differences were found between successful and unsuccessful signals in area under HF signal, LF amplitude, LF to R time, HF ratio, and HF area × HF ratio. A receiver operating curve of HF area × HF ratio produced an area under the curve of 0.89. An HF area × HF ratio of 3.1 distinguished successful from unsuccessful signals with 100% specificity and 81% sensitivity.

CONCLUSION Automated signal analysis retrospectively differentiated successful from unsuccessful signals in patients undergoing RFCA for WPW. This software may improve the safety and efficacy of RFCA in children.

KEYWORDS Ablation; Electrophysiology; Pediatric electrophysiology; Radiofrequency catheter ablation; Signal analysis; Wolff-Parkinson-White syndrome

ABBREVIATIONS AP = accessory pathway; **HF** = high frequency; **LF** = low frequency; **RFCA** = radiofrequency catheter ablation; **WPW** = Wolff-Parkinson-White

Introduction

The treatment and therapies for Wolff-Parkinson White Syndrome (WPW) have undergone remarkable progress in the past 40 years, from the initial surgical ablations in the 1960s to the current modern use of radiofrequency (RF) and cryoenergy delivered at cardiac catheterization.[1] While the tools used to ablate accessory pathway (AP) tissue in patients with WPW have advanced over the past 20 years, only marginal changes have been made in the approach to the distal ablation probe signal analysis over this time. Currently multiple factors are important to successful ablation of an AP, including catheter technology, catheter stability, operator experience, and careful analysis of the signal and electrograms on the distal ablation probe. Experienced electrophysiologists often can recognize a signal that, when ablated, will successfully lead to disruption of AP conduction. However, in addition to this rather subjective form of signal analysis, measurement tools and strategies are currently used to help confirm suspicion for being in the correct location to apply RF or cryotherapy.[2–4] Examples of such approaches include measuring local AV time or measuring the time from the local ventricular electrogram to the surface delta wave. These measurement, however, may also be somewhat subjective and therefore inexact. Although success rates using these techniques are good, ranging from 90% for right-sided pathways and up to 97% for left-sided pathways, there is still a 3%–10% failure rate for ablating WPW.[5,6] This failure rate leaves

Address reprint requests and correspondence: Dr. Scott R. Ceresnak, Albert Einstein College of Medicine, Division of Pediatric Cardiology, Pediatric Arrhythmia Service, The Children's Hospital at Montefiore, 3415 Bainbridge Ave, Rosenthal 1, Bronx, NY 10467-2490. E-mail address: ceresnak@yahoo.com.

1547-5271/$ -see front matter doi:10.1016/j.hrthm.2011.08.022

room for novel ideals and techniques to improve the overall success rate.

In addition to improving success rates with ablation, there is also the goal of performing a successful ablation with the smallest number of RF and Cryo lesions or cryolesions. Often multiple lesions are placed in the process of finding the exact location of success during ablation for WPW.[6] Limiting the number of lesions placed is of paramount concern when ablating in young children, as animal data have shown that lesion size may grow and expand over time.[7,8] Thus, there is room for novel techniques that not only improve efficacy but also reduce the number of lesions required for a successful ablation.

In an effort to improve the success rates for ablation of WPW and to reduce the number of lesions required for a successful ablation, we have developed an electronic, fully automated, objective signal analysis tool to help confirm whether an electrical signal will prove to be a successful location for ablation of an AP in patients with WPW. We hypothesize that signal analysis for ablation of WPW can (1) be fully electronically automated and (2) retrospectively predict signals that result in a successful ablation.

Methods

After approval was obtained from the Institutional Review Board of Montefiore Medical Center, a retrospective analysis of ablation signals on all patients who underwent RF ablation for WPW at the Children's Hospital at Montefiore between 2008 and 2010 was performed. The inclusion criteria were patients younger than 21 years who had a successful RF ablation with loss of AP conduction in <5 seconds and had medium-term success with no recurrence at 3 months of follow-up. The exclusion criteria were patients who had a cryoablation, had atrial or ventricular pacing during the successful ablation, had congenital heart disease, or had multiple APs. Signals obtained for analysis were acquired in sinus rhythm exclusively, although transient episodes of atrial pacing or ventricular pacing during the case did not exclude the patient, provided the signals for analysis were obtained during preexcited sinus rhythm.

The following data were obtained for each patient: demographic data (age, height, weight), location of AP, time to loss of preexcitation, local AV and presystolic times, ablation signal data (described below), and most recent follow-up data. Local AV time and presystolic time from the surface QRS were measured in milliseconds by a blinded electrophysiologist on the successful and unsuccessful standard ablation probe signals. Local AV time was defined as the time (in milliseconds) from onset of the atrial electrogram to onset of the ventricular electrogram on the distal ablation probe. Presystolic time was defined as the time (in milliseconds) measured from onset of the local ventricular electrogram on the distal ablation probe to onset of the surface delta wave measured in any lead.

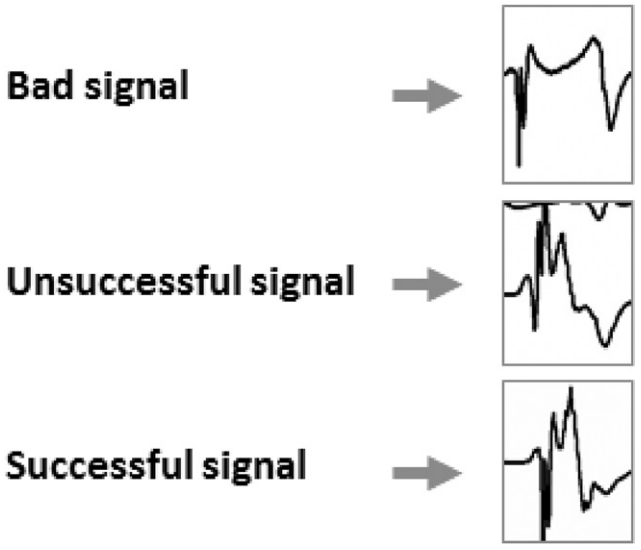

Figure 1 Representative examples from a patient with a *bad* signal, an unsuccessful signal, and a successful signal. For the purposes of this investigation, a *bad* signal was defined as a signal where no radiofrequency lesion was placed, an unsuccessful signal was defined as a signal where a radiofrequency lesion was placed but did not result in loss of accessory pathway conduction, and a successful signal was defined as a signal where a single radiofrequency lesion resulted in loss of accessory pathway conduction in <5 seconds.

Signal classification and definitions

For the purposes of this investigation, a *bad* signal was defined as a signal where no RF lesion was placed. An *unsuccessful* signal was defined as a signal where an RF lesion was placed but did not result in loss of AP conduction. A *successful* signal was defined as a signal where an RF lesion resulted in loss of AP conduction in <5 seconds. Examples of *bad*, unsuccessful, and successful signals are shown in Figure 1.

Ablation probe signal data extraction process

The raw data from the distal ablation probe were extracted on all patients from the GE CardioLab computer (GE Healthcare, Piscataway, NJ, USA). The data were exported as text data to a USB drive. Proprietary software was written to analyze the raw ablation probe analog signal data. Using a Butterworth filter, the ablation probe signal was filtered and split into 2 components: low frequency (LF) and high frequency (HF). The LF components of the signal were defined as between 0 and ≤0.02 Hertz and the HF components were defined as between >0.02 and ≤0.45 Hertz. These novel signals were analyzed as described below.

Novel signal analysis

The software was programmed to automatically identify and/or calculate the following variables on the novel signals (Figure 2): start of the HF signal, peak of the LF signal, peak of the R wave from surface ECG lead I, amplitude of the LF and HF signals, and area under the LF and HF signals. Graphical examples of each of these variables are shown in Figure 2. When starting to analyze these signals,