Utility of Noninvasive Arrhythmia Mapping in Patients with Adult Congenital Heart Disease

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KEYWORDS

• Congenital heart disease • Catheter ablation • Anatomy • Three-dimensional mapping • Noninvasive • Outcomes

KEY POINTS

- Previous body surface mapping approaches lacked integration of the individual anatomy, and therefore have rarely been used in clinical practice in the last decade.
- A recently introduced noninvasive multielectrode electrocardiographic mapping system (ECVUE; CardioInsight Technologies Inc, Cleveland, OH, USA) combines 3-dimensional (3D) reconstruction of the cardiac anatomy from computed tomography scans with simultaneous recording of the cardiac activation from 252 surface electrocardiographic electrograms.
- The noninvasive nature of the 3D multielectrode mapping system helped to differentiate multiple targets in some patients or rare ectopy over a longer mapping time of several hours.
- Documentation of the location of the critical substrate allowed an informed choice regarding conventional versus remote-controlled navigation techniques, which in turn resulted in limited procedure time and radiation exposure.
- The 3D multielectrode mapping system helped avoid the unnecessary risk of an invasive procedure in patients with palpitations resulting from sinus tachycardia.

INTRODUCTION

Arrhythmia management in patients with adult congenital heart disease (ACHD) is a challenge on many levels, as tachycardic episodes may lead to hemodynamic impairment in otherwise compensated patients even if episodes are only transient.[1,2] Arrhythmias are in all the different types of congenital cohorts a marker for significant morbidity and mortality.[2–6] Owing to the underlying condition, challenges can present in various aspects such as the corrected anatomic situation after surgery, the inherent conduction properties of a potentially abnormally located or otherwise impaired conduction system, and the arrhythmia substrate itself in the form of fibrosis and/or surgically acquired scars.[7] This presentation may give rise to a multitude of arrhythmia

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substrates, which can vary from infrequent atrial or ventricular ectopy to sustained reentrant tachycardias.[3,8–10] Some congenital conditions, such as Ebstein anomaly, have a high incidence of multiple accessory pathways, giving rise to atrioventricular (AV) reentrant tachycardia; this may include several accessory pathways or the normal conduction system, resulting in variable AV reentrant circuits, which can confuse the invasive electrophysiologist and increase the complexity of any catheter ablation procedure.[11,12] However, as ACHD patients are usually young and active members of society, any curative approach to their arrhythmias leads to a dramatic change in their clinical course such that catheter ablation is advocated in preference to lifelong antiarrhythmic medication by many interventional electrophysiologists. Recently several technical advances, including 3-dimensional (3D) image integration, 3D mapping, and remote magnetic navigation, have been introduced to facilitate curatively intended ablation procedures in this special patient cohort.[13–15] This review attempts to outline the role of a novel technology of simultaneous, noninvasive mapping in this patient cohort, and gives details of the authors' single-center experience.[16–18]

SIMULTANEOUS VERSUS SEQUENTIAL MAPPING

To allow successful catheter ablation, a detailed understanding of the arrhythmia and the exact localization of the critical substrate (eg, focal source of the arrhythmia or critical isthmus of a reentry) needs to be identified.[7,19] Although body surface electrocardiogram (ECG) mapping has been available for a long time, most invasive mapping systems have used a sequential recording approach, which requires a stable arrhythmia.[15,20] Any infrequent, irregular, or unstable arrhythmia is essentially "nonmappable" using a sequential approach, as the activation pattern is constantly changing. Moreover, infrequently occurring arrhythmias that are difficult to provoke under catheter laboratory conditions pose a challenge in the electrophysiology (EP) laboratory, as the physiologic conditions of the sympathetic drive might be diminished, especially if invasive procedures require sedation of the patient.

Body surface mapping approaches of the past lacked the integration of the individual anatomy, and therefore have been used rarely in clinical practice in the last decade. The recent introduction of the noninvasive multielectrode ECG mapping (ECM) system (ECVUE; CardioInsight Technologies Inc, Cleveland, OH, USA) has now closed this gap.[17,18] It combines the 3D reconstruction of the cardiac anatomy from computed tomography (CT) scans with the simultaneous recording of the cardiac activation from 252 surface ECG electrograms. Using an inverse solution, virtual unipolar electrograms are reconstructed on the epicardial surface of either the atrial or ventricular chambers. This panoramic mapping system allows assessment of a global activation sequence from a single beat in a noninvasive fashion. Its use so far has been reported in patients with atrial or ventricular tachycardia, accessory pathway dependent tachycardia, and atrial fibrillation.

METHODS

Patient Population

Of a total cohort of 27 patients undergoing ECM at the authors' institution from November 2012 to May 2013, 14 had an underlying ACHD condition. Table 1 gives an overview of the detailed conditions. Patients were recruited from the waiting list for invasive EP studies and gave consent for the noninvasive mapping study using the ECM in addition to the invasive EP procedure. In cases of rare

Table 1
Demographics of patients with adult congenital heart disease

No. of patients	14
Age (y)	32.8 (24.6–47.4)
Gender	9 F, 5 M
Underlying heart disease	1 D-TGA + arterial switch 2 CCTGA 1 AVSD 1 LSVC + mitral valve disease 1 DiGeorge syndrome 2 Coarctation of the aorta 2 Fontan 2 Ebstein 1 Double-chambered RV + VSD repair 1 ASD repair
Previous ablation	9 (6 AT/AF, 1 WPW, 2 VE)
Spontaneous ablation target	9
Provocation during EP study	12

Abbreviations: ASD, atrial septal defect; AT/AF, atrial tachycardia/atrial fibrillation; AVSD, atrioventricular septal defect; CCTGA, congenitally corrected transposition of the great arteries; D-TGA, dextro-transposition of the great arteries; EP, electrophysiology; LSVC, left superior vena cava; RV, right ventricle; VE, ventricular ectopy; VSD, ventricular septal defect; WPW, Wolff-Parkinson-White syndrome.