Use of computational electrocardiographic mapping to guide successful surgical cryoablation of a premature ventricular contraction originating near an intramural anomalous coronary artery

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Introduction

Anomalous coronary arteries are rare. A malignant course occurs when the anomalous coronary artery takes an interarterial course between the aorta and pulmonary artery (with or without an intramural segment) and is associated with ischemia and an increased risk of sudden cardiac death owing to extrinsic compression.[1–5] Although the occurrence of ventricular fibrillation has been reported in patients with malignant anomalous coronary arteries,[6] ventricular arrhythmias have not been previously localized to the site of an anomalous coronary artery.

We report for the first time the association of a premature ventricular contraction (PVC) originating near an anomalous right coronary artery (RCA) and the successful use of a novel computational mapping algorithm based solely on a standard 12-lead electrocardiogram (ECG) to guide concomitant surgical PVC ablation during coronary artery unroofing.

Case report

A 40-year-old female patient presented with symptomatic palpitations and was found to have 8% burden of monomorphic PVCs of inferior axis left bundle branch block morphology (Figure 1A) despite titration of metoprolol and flecainide doses. During work-up for PVC ablation, cardiac computed tomography revealed an anomalous RCA originating from the left sinus of Valsalva with an interarterial, intramural course (Figure 1B). Given the intramural course, she was referred for surgical unroofing of the anomalous RCA[7] and concomitant surgical cryoablation of the PVC.

KEY TEACHING POINTS

- We describe the unique case of a premature ventricular contraction (PVC) localized to the site of an anomalous, interarterial, intramural coronary artery.
- We demonstrate the use of a novel, noninvasive 12-lead electrocardiogram (ECG)–based mapping system to localize PVCs.
- Our novel ECG mapping system was used successfully to guide concomitant surgical cryoablation of a PVC during coronary artery unroofing surgery.

A novel perioperative surgical PVC ablation workflow was designed using a noninvasive 12-lead ECG-based mapping system (vMap; Vektor Medical Inc, Carlsbad, CA). In the outpatient clinic, the patient's PVCs were captured using a standard 12-lead ECG acquisition system (Muse; GE Medical, Chicago, IL) and digitized using custom software. The ECG data file was imported into the computational ECG mapping system. Patient characteristics (absence of scar or left ventricle dilation) were recorded, and the PVC exit site was localized to the septal right ventricular outflow tract underneath the pulmonic valve, near the course of the anomalous RCA. The site of origin was visualized on a 3D model (Figure 1C) within 36 seconds of total mapping time.

Subsequently, the patient was placed under general anesthesia and underwent sternotomy. She was initiated on cardiopulmonary bypass, and the heart was arrested. An incision was made in the pulmonary artery, and 3 contiguous cryoablation lesions (total 1 cm^2) were placed at the PVC exit site localized to the septal right ventricular outflow tract

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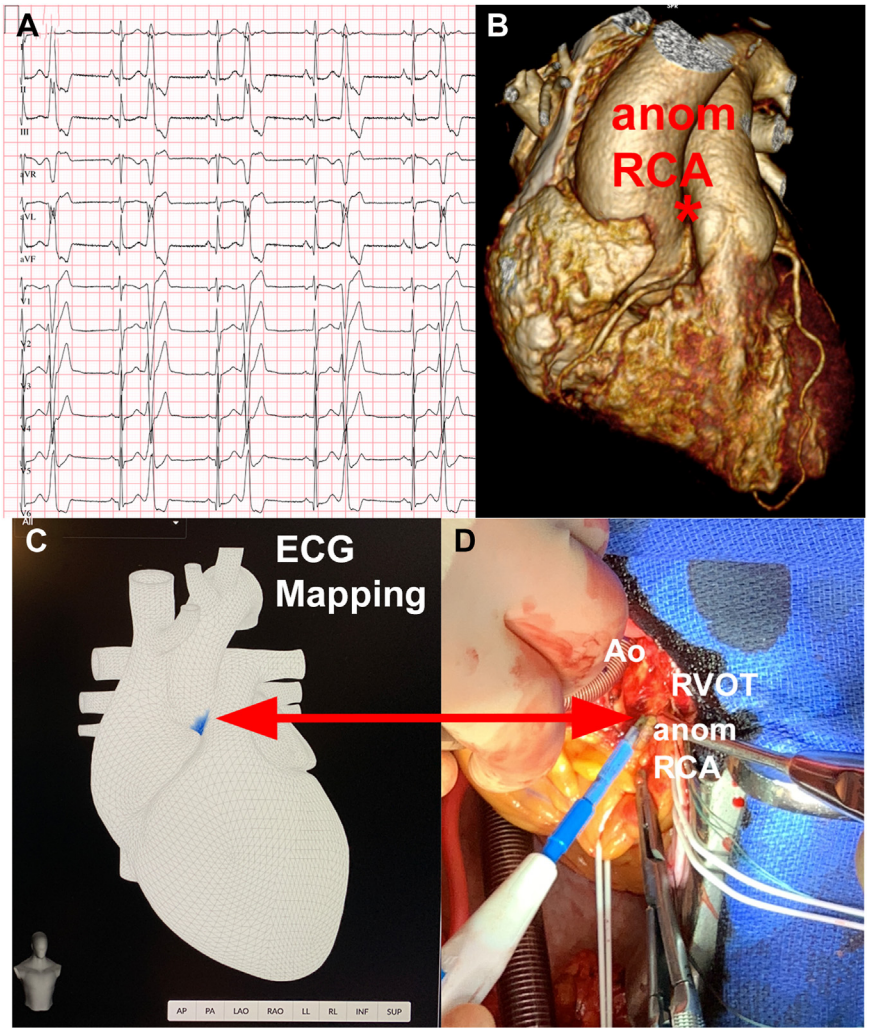

Figure 1 **A:** Electrocardiogram (ECG) showing a bigeminal premature ventricular contraction (PVC). **B:** Preablation cardiac computed tomography revealed an anomalous interarterial, intramural right coronary artery (anom RCA). **C, D:** A novel computational ECG mapping system localized the PVC to the septal right ventricular outflow tract (RVOT) near the course of the anomalous RCA (**C**) and guided successful concomitant surgical PVC cryoablation and coronary unroofing (**D**).

underneath the pulmonic valve (Figure 1D) using a cryoablation probe (90 seconds, -50°C). The pulmonary artery incision was then sutured. Coronary artery unroofing of the intramural RCA was performed, after which the heart was reperfused, and the patient was weaned off bypass uneventfully.

Postoperatively, the patient recovered without any complications. There were no PVCs on telemetry, and she was discharged from the hospital in 4 days. Her palpitations and PVCs were eliminated durably. An event monitor obtained at 4 months after surgical cryoablation showed 3% PVC burden (of different PVC morphology), and at 2-year follow-up, there was <1% PVC burden.

Discussion

Anomalous coronary arteries with a malignant course are associated with an increased risk of arrhythmias and sudden cardiac death,[4–6] though ventricular arrhythmias have not been previously localized to the site of an anomalous coronary artery. This is the first report associating a PVC to the site of an anomalous, interarterial, intramural coronary artery.

PVC localization and surgical cryoablation were guided by the use of a novel ECG mapping system. ECG data are imported into the computational mapping system that then localizes and integrates the highest probabilistic location for the PVC focus onto the patient's computed tomography 3D reconstruction model. This algorithm is based on forward-solution computational simulation libraries of arrhythmias, including PVCs originating from sites around the heart with or without scar. The simulation libraries are based on 3D finite element models of monodomain cardiac action potential propagation using the Continuity simulation environment. The models consist of detailed

descriptions of cardiac geometry, myofiber orientation, and scar. The simulation library incorporates >1 million simulated arrhythmia cycles.

There are many advantages to this technique. This method is less time consuming than traditional invasive catheter-based mapping and is easy to incorporate into any clinical workflow, including mapping in an outpatient clinic using standard, widely available ECG equipment. It has been shown to be a rapid and accurate technique, with a recent blinded multicenter clinical trial showing segmental accuracy of 100% [95% CI: 96%–100%] and spatial accuracy of 11 mm [95% CI: 5–22 mm] for PVC localization.[8]

The use of a noninvasive 12-lead ECG–based mapping system to successfully guide surgical ablation of ventricular arrhythmias is a novel approach that can expand the indications for concomitant arrhythmia ablation during cardiac surgery for other indications. The familiarity of the 12-lead ECG to all physicians, including cardiac surgeons, is attractive, as it can be easily integrated into any clinical preprocedural workflow.

Conclusion

For the first time, we describe the association of a PVC to the site of an anomalous RCA and the use of a novel arrhythmia ECG mapping algorithm to localize and guide successful concomitant surgical cryoablation during coronary artery unroofing surgery, resulting in long-term elimination of PVCs.

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