BRIEF REPORT

Utility of an innovative cloud-based storage software for ablation redo procedures: Initial experience

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Introduction

Different types of arrhythmias are nowadays treated with catheter radiofrequency ablation procedures in which electroanatomical mapping systems play a fundamental role in achieving a safe and effective clinical endpoint improving the procedure efficiency.

Some patients may undergo multiple ablation procedures due to recurrences or onset of new arrhythmias. For these patients, before the redo procedure, it might be useful to investigate and analyze the ablation parameter of the first procedure. Data such as ablation location, impedance drop, contact force, or duration may help the physician in anticipating the origin of the arrhythmia that brought back the patient.

A cloud-based storage software may help in collecting all the relevant procedure data facilitating retrieval and analysis. The CARTONET (Biosense Webster) cloud-based smart storage solution gives electrophysiologists the ability to review, analyze, and share their CARTO 3 system cases with the goal of improving procedure efficiency and patient outcomes (Figure 1). CARTONET utilizes machine learning and leverages the teamplay Cloud Platform of Siemens Healthineers, which meets industry best practices of security and privacy and supports compliance with HIPAA (Health Insurance Portability and Accountability Act) and GDPR (General Data Protection Regulation). The CARTONET features include backup and storage of cases with queryable-cloud-based CARTO 3 System, a dashboard of cases with relative data including multiple expandable layers of information and analytics.[1]

In a previous publication,[2] the CARTONET software was used to evaluate the adherence to an ablation protocol and to examine possible predictors of additional touch-up ablations within the same procedure. However, the machine learning software was not used as a tool to gain information for redo procedures.

We used CARTONET to analyze the ablation procedures involving patients that came back to the lab for a redo. We present 2 cases and how the CARTONET data relative to the first procedure correlated with the findings of the redo procedure.

Workflow description

The 2 cases presented here refer to patients that underwent a first ablation procedure of atrial fibrillation (AF) at our center and that came back for a redo procedure due to an atypical atrial flutter.

For each patient, in the first procedure we reconstructed an accurate electroanatomical map of the left atrium with the multielectrode mapping Pentaray catheter (Biosense Webster). The voltage map color bar was set to 0.05–0.24 mV when mapping in AF and to 0.05–0.5 mV when mapping in sinus rhythm (SR).

Ablation of the pulmonary veins was performed with the ThermoCool SmartTouch SF catheter (Biosense Webster) according to the CLOSE protocol.[3] The target ablation values are ablation index (AI) of 430 in the posterior, roof, and inferior sections and 500 in the anterior sections, interlesion distance $\leq$6 mm, average force $\geq$5 g, impedance drop $\geq$5 Ω, and catheter tip stability equal to 3 mm.

For each patient, before the redo procedure, we examined the AF procedure on CARTONET using the Advance Analysis and the Ablation Analysis modules that allow retrospective analysis including manual annotation and machine

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KEY FINDINGS

- CARTONET software allows analysis of atrial fibrillation ablation procedures through retrospective examination of procedural data, enabling physicians to evaluate and review specific details.
- It is possible to predict potential reconnection sites during ablation redo procedures through a multiparameter analysis.
- The cloud storage system could have a significant impact on clinical management, allowing physicians to evaluate their effectiveness and efficiency in redo ablation procedure.

learning–based classification of ablation sites by anatomical structure. For each ablation site, it is also possible to review the ablation parameters.

The ablation sites are color-coded tags indicating areas where radiofrequency energy was delivered during an ablation procedure. These are colored according to the value selected in the drop-down menu: average force, base impedance, site ablation duration, force time index, impedance drop, maximum power, maximum temperature, tag index, stability, site creation time, and site time intervals. Furthermore, the ablation tags can also be colored based on their anatomical location: left and right wide area circumferential ablation (WACA), roof line, left and right carina, posterior line, inferior line, mitral line, anterior line, left atrial appendage isolation, left atrial appendage sporadic.

Lesions associated with the WACA are represented by thicker lines connecting the tags, while thinner lines identify additional ablation lines other than the right or left WACA. The cloud-based software performs an automatic analysis of the WACA lines, highlighting possible reconnection sites along the pulmonary veins based on a machine learning algorithm. Visually, these reconnection sites are indicated by interruptions in the lines connecting the ablation sites along the WACA.

The system currently does not provide automatically potential reconnection sites on additional lines outside the WACA. In the 2 cases reported in this report, we focused on the additional ablation lines performed during the first procedure beside pulmonary vein isolation, looking for possible parameters that could be informative of possible reconnections along these additional lines.

First, for each AF procedure considered, we examined in CARTONET the ablation lines, verifying the correct anatomical location assignment. Next, for each additional ablation line, we analyzed all the ablation parameters (impedance, interlesion distance, AI, average force, and stability) and their values, looking for possible clusters (>2 consecutive) of ablation points that did not respect the predefined target values. If such cluster of points was found, we checked if it matched with the culprit area found during mapping in the redo procedure. At the end of the redo procedure, after SR restoration, bidirectional block with bipolar and pacing

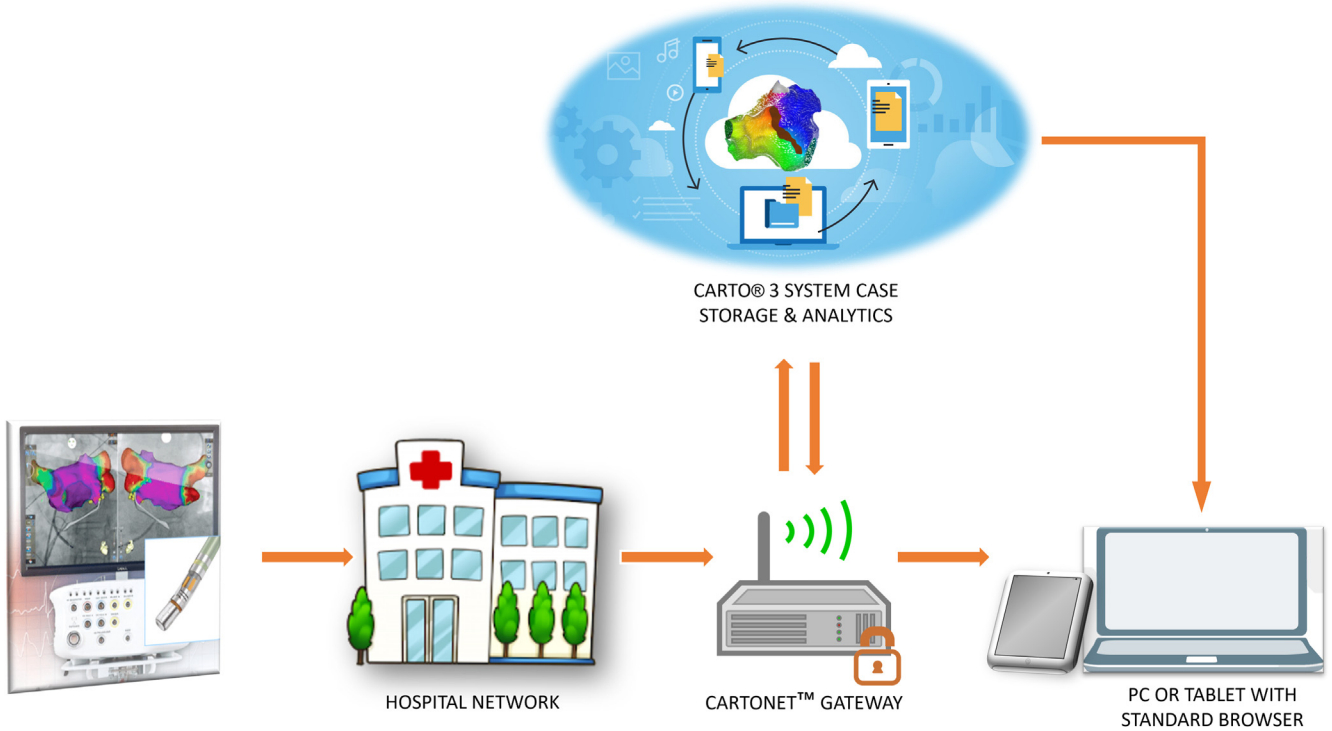

Figure 1 Schematic of the CARTONET cloud-based software architecture.

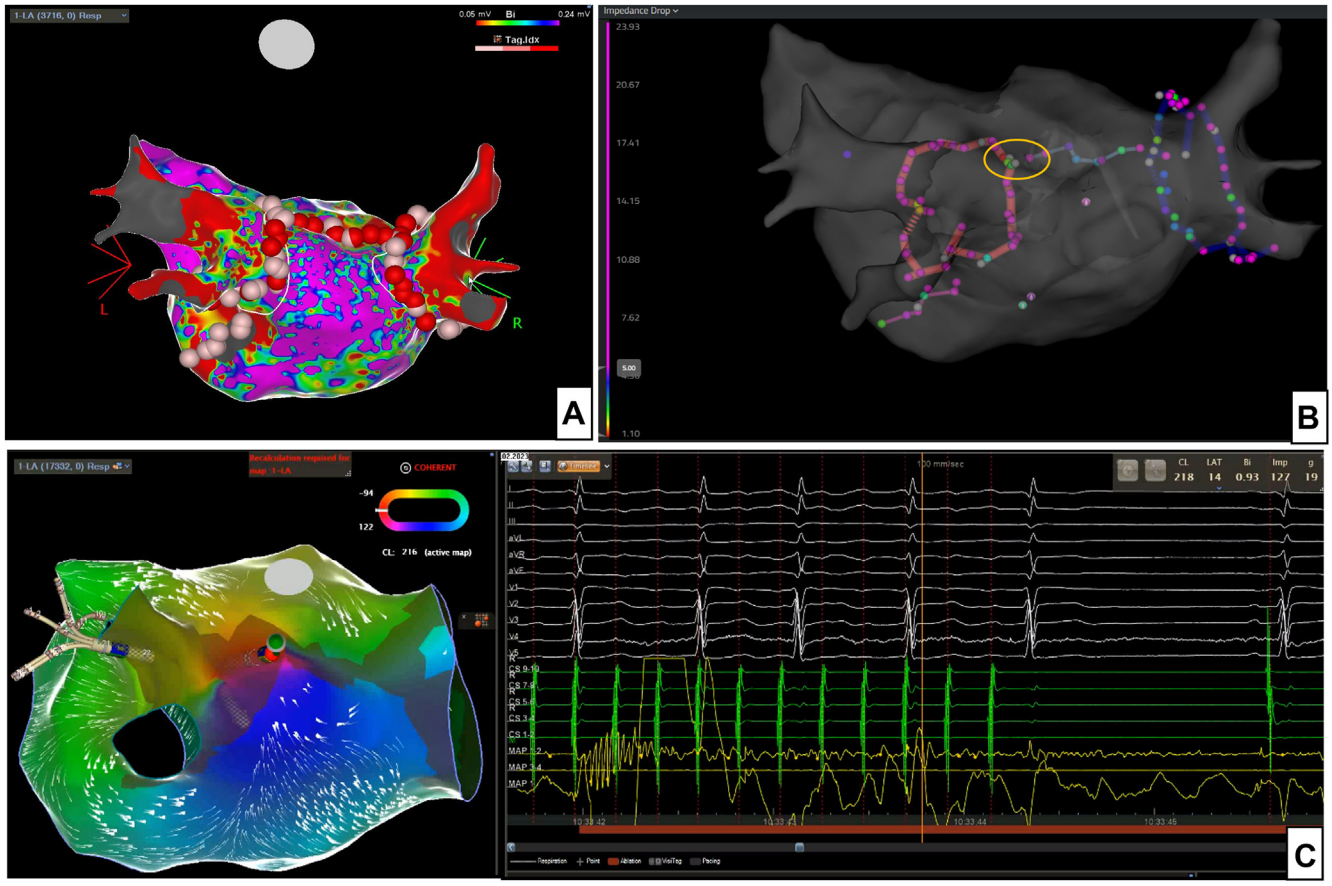

Figure 2 A: Substrate map of the left atrium during atrial fibrillation and ablations performed during the first procedure. B: CARTONET analysis of each ablation point color-coded based on impedance drop. We visually indicated with an orange circle an area with more than 2 consecutive points having an impedance drop <5 Ω along the additional lines, excluding the wide area circumferential ablation line. C: The activation map during the redo procedure and catheter ablation position at the site where sinus rhythm was restored during ablation, as shown on the intracardiac electrograms on the left.

map across the line of ablation was tested. Furthermore, a postablation induction test with isoprenaline was performed in both cases.

Case 1

In March 2020, a 66-year-old man underwent an ablation procedure for persistent AF. All the pulmonary veins were successfully isolated. Moreover, based on the substrate map obtained during AF, the physician performed additional ablation lines on the roof, in the posterior wall, and along the mitral isthmus. The goal of these additional ablation lines was to homogenize low-voltage areas and fragmented potentials (Figure 2A). The procedure time was 130 minutes and the ablation points, including these required for the WACA, were 78.

In February 2023, the patient returned to our electrophysiology lab with an atypical atrial flutter. Before the second procedure, we analyzed the AF case with CARTONET. After all the anatomical segments were correctly assigned, we checked all the ablation parameters and noticed that the impedance drop target value was not met in the roof line at the level of the left superior pulmonary vein (Figure 2B).

Following the CARTONET analysis, the patient underwent a second ablation procedure. The critical isthmus consisted of the portion between the left WACA and the roof line performed during the first procedure as suggested by CARTONET analysis. At this location, ablation resulted in restoration of SR (Figure 2C). Bidirectional block across the line was confirmed, and the induction test with isoprenaline was negative.

The total procedure time in the redo was 70 minutes with a total of 26 ablation points.

Case 2

In June 2022, a 77-year-old woman underwent an ablation of early persistent AF. The patient was in SR at the beginning of the procedure. Following WACA of the pulmonary veins, it was decided to isolate the posterior box because of the anomalous propagation of the electrical impulse.

Subsequently, programmed stimulation with 3 extra stimuli and the administration of isoprenaline were performed. During the induction test, AF was induced with synchronization phases in atypical flutter. The activation map highlighted perimitral re-entry with critical isthmus on the anterior

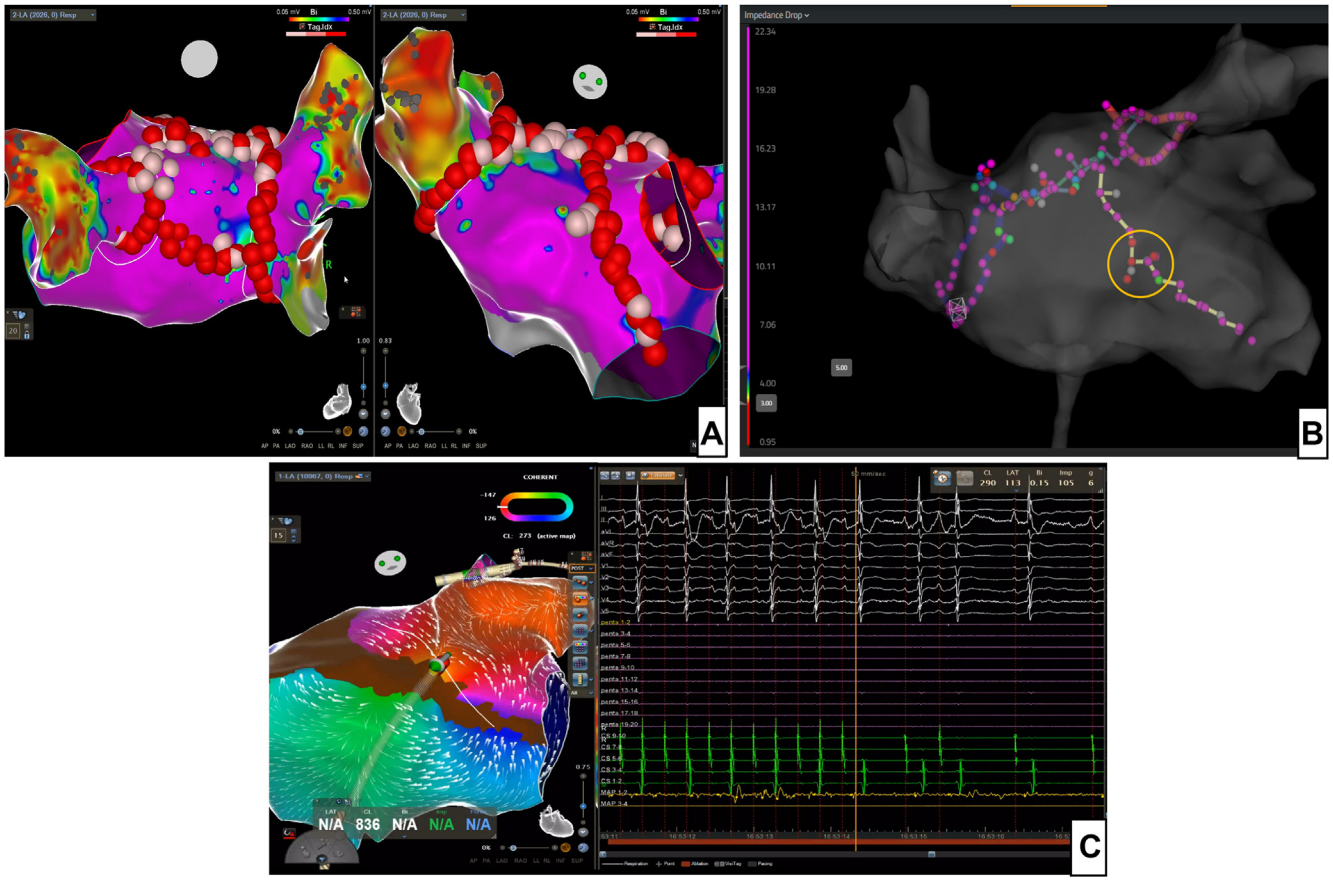

Figure 3 A: Substrate map of the left atrium during atrial fibrillation and ablations performed during the first procedure. B: CARTONET analysis of each ablation point color-coded based on impedance drop. We visually indicated with an orange circle an area with more than 2 consecutive points having an impedance drop <5 Ω along the additional lines, excluding the wide area circumferential ablation line. C: The activation map during redo procedure and catheter ablation position at the site where sinus rhythm was restored during ablation, as shown on the intracardiac electrograms on the left.

portion of the left appendage. An ablation line was created from the left superior pulmonary vein to the mitral annulus, obtaining restoration of SR (Figure 3A). At the end of the first procedure, bidirectional block across the anterior line was confirmed.

The procedure time was 150 minutes and the ablation points, including these required for the WACA, were 96.

In February 2023, the patient returned to our electrophysiology lab with atypical atrial flutter. When analyzing the case in CARTONET, we noticed that among the additional lines performed during the first procedure, the impedance drop of 5 Ω was not satisfied on the anterior line (Figure 3B), corresponding to an area where, during the first procedure, catheter instability led to AI recalculation.

In the redo procedure, the critical isthmus found by local activation time mapping involved the portion of the septal-anterior line. Ablations in the septal line and in the posterior portion of the left WACA led to SR restoration (Figure 3C). Bidirectional block across the line was confirmed and the induction test with isoprenaline was negative.

The total procedure time in the redo was 90 minutes with a total of 28 ablation points.

Discussion and conclusion

We report our first experience using CARTONET to successfully predict possible reconnection sites following AF procedures. With the 2 cases presented, we showed our preliminary experience in the use of CARTONET for reconnection prediction in complex procedures that do not involve only pulmonary vein isolation. Of all the ablation parameters, we found that areas with an impedance drop below 5 Ω correspond to culprit regions in the redo procedure. More cases and additional analysis are needed to confirm this possible relation.

Furthermore, analyzing the cases with CARTONET before the redo procedure may lead to efficient procedural workflows and shorter mapping and ablation times.

CARTONET has the potential to impact clinical care significantly by enabling physicians to assess and review their performance more easily. Incorporation of these tools in studies and registries may aid analysis of the complex data generated during ablation procedures.

This cloud-based storage system may impact clinical care significantly and improve procedural outcomes.

Further prospective studies are needed to investigate CARTONET potential in improving the efficiency and efficacy in redo ablation procedures.

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Ethics Statement: The research reported in this paper adhered to CARE case report guidelines.

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