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Introduction

Rhythmia™ is a novel, high-density automated electro-anatomic contact mapping system designed to facilitate assessment and ablation of both atrial and ventricular arrhythmia substrates. The system utilizes a 64-pole steerable basket catheter (magnetically located) that is used to create a shell of the chamber of interest and simultaneously collect very high-density, low-noise electrogram information. Electrogram collection is automated, so activation patterns and scar maps containing several thousand points are acquired routinely. Any ablation catheter can be used. Location of the ablation catheter is currently impedance based and requires an intracardiac catheter as a positional reference (e.g., a coronary sinus catheter), although there are plans for magnetic guidance of the ablation catheter.

The Orion™ High Resolution Mapping Catheter is at the heart of the system (Figure 1). The catheter has bidirectional steerability and a variable profile to facilitate access to complex anatomic structures. Electrodes are printed onto the surface of the splines of the catheter and all of the signals assessed are contact electrograms. The recording system produces very low-noise electrograms. The case workflow involves accessing the chamber of interest with the Orion™ Basket catheter. If the arrhythmia is ongoing, collection of the chamber geometry can be combined with collection of electrograms for endocardial voltage and activation timing. Typically, multiple electrical maps will be made to assess, for example, integrity of a line of block or a new arrhythmia mechanism. Because electrogram collection is high density and automatic, collection of new maps is seldom time consuming.

Electrograms are used for mapping only when they are close to the shell of the cardiac chamber. This distance is programmable, but defaults to 2 mm – so Rhythmia™ essentially yields contact maps. Electrogram collection is continuous whilst the basket catheter is in contact with the surface. Activation patterns are assessed based on a timing reference. To ensure that the collected timing points are related only to the arrhythmia of interest, an automated comparison of the activation sequence is made for each collected beat. This ‘propagation reference’ can be a second intracardiac signal, or a surface electrocardiograph. Automated acceptance or rejection of mapping points is based on electrogram stability, location stability and the phase of the respiratory cycle. Annotation of timing of individual points is made after comparison with near neighbors, which is particularly important in areas with multiple potentials. Individual mapping points can be edited manually, but in practice this is almost never necessary.

Electrograms are collected as unipoles using either the surface electrocardiograph or (preferably) an IVC catheter as the indifferent electrode. Bipolar electrograms are computed by default from adjacent electrodes on the basket catheter. Both unipolar and bipolar signals can be displayed, and it is very useful to be able to review individual contact electrograms from apparent zones of slow conduction or critical isthmuses when planning ablation strategies.

Rhythmia™ can display a variety of map formats. Perhaps the most useful is side-by-side voltage and activation maps. Either can be based on unipolar or bipolar electrograms, but most will use bipolar maps. Figure 2 shows an example of bipolar voltage and activation maps taken in sinus rhythm in

Figure 1: Orion™ High Resolution Mapping Catheter.
a patient with recurrent atrial flutter after a previous catheter ablation, which had included pulmonary vein isolation and a ‘roof’ line from the LSPV to the RSPV. There is a large deficiency in the roof line (left panel), and electrical activation can be seen to pass through the gap in the line. Atrial flutter was later induced utilizing this deficiency, and was subsequently controlled by closing the line.

Bipolar electrograms can also be displayed as a fractionation map based on the number of voltage peaks in each individual electrogram. Figure 3 shows an example of fractionation mapping from a patient with persistent atrial fibrillation. Ablation in the areas with maximal fractionation (red on the map) resulted in termination of atrial fibrillation to a mitral, isthmus-dependent atrial flutter.

This article will present a series of cases of complex arrhythmias treated using the Rhythmia™ system. All are atrial arrhythmias. Of the cases examined:

- Two are unusual right atrial flutters,
- One is a series of patients with atrial fibrillation undergoing pulmonary vein isolation,
- One is a microreentrant atrial tachycardia,
- Three are left atrial flutters complicating atrial fibrillation ablation, and
- One is a de novo left atrial flutter in a patient with a remote mitral valve replacement.

The common threads in these case examples are the utility of the Rhythmia™ system in assessing the integrity of linear block, and the utility of very high-density contact mapping in rapidly and accurately tracing reentrant and automatic arrhythmias. All of the cases are illustrated by still images. Because of the very high-density mapping, Rhythmia™ is a system that is best appreciated with moving images.
CASE 1

History

The patient is a 61-year-old man with controlled hypertension, managed with Lisinopril 10 mg daily, but no other structural heart disease. He is very physically fit and is a frequent marathon runner. He presented with paroxysmal atrial fibrillation that was resistant to therapy with Flecainide. He underwent his first catheter ablation procedure 5 years ago. During this procedure, AF was induced after pulmonary vein ectopy during an isoproterenol infusion. Pulmonary vein isolation did not restore sinus rhythm, so ablation of complex fractionated atrial electrograms was performed, followed by a ‘roof’ line from the left superior pulmonary vein to the right superior pulmonary vein. Sinus rhythm was ultimately restored by DC cardioversion. He was treated with flecainide for 6 weeks after ablation, and subsequently remained arrhythmia-free for more than four years. His second catheter ablation was precipitated by an arrhythmia recurrence that was documented as an atypical atrial flutter that was resistant to flecainide. The patient was highly symptomatic with the atrial flutter, so we elected to proceed with a second ablation procedure.

Procedure

The procedure was performed under general anesthetic and during anticoagulation with Xarelto, supplemented with heparin (target ACT 350-400 seconds) after venous access had been secured. Double transseptal puncture was performed using a radiofrequency transseptal needle. A Zurpaz sheath and a 120° Heartspan sheath were introduced into the left atrium. A 3D electroanatomic map was obtained during ongoing atrial flutter, using an Orion™ basket catheter advanced through the Heartspan sheath. The map was based on more than 20,000 individual electrograms obtained over 23 minutes, plus 5 minutes of fluoroscopy.

Figure 4 shows anteroposterior and posteroanterior views of the LA activation sequences obtained at different phases of the tachycardia. Note that pulmonary vein isolation was mostly satisfactory. The signal in the left superior pulmonary vein (LSPV) was far field from the left atrial appendage. Activation was superior-inferior anteriorly (left panel) and inferior-superior posteriorly (right panel). There was a defect in the roof line (arrow, right panel), consistent with the idea that this was a critical isthmus in the tachycardia circuit. Activation proceeded anteroposteriorly through the interatrial septum and mitral isthmus (Figure 5). Mid-diastolic activation was recorded from the apparent defect in the roof line that had been constructed at the index ablation (Figure 6). Figure 7 shows fractionated mid-diastolic electrogram recorded from this location using...
the dynamic probe (a Rhythmia™ tool that shows the closest electrogram at any point on the chamber surface). Ablation at this location resulted in restoration of sinus rhythm. No further atrial arrhythmias could be induced, despite rapid atrial pacing.

**Comment**

Atrial flutters are a common complication of linear ablation in the left atrium, and they are usually assessed by 3D electroanatomic mapping. Entrainment pacing can be problematic in these cases, because the arrhythmia frequently degenerates into atrial fibrillation. This case turned out to be straightforward, and the circuit was interrupted with a few radiofrequency lesions. High-density mapping facilitated assessment of the arrhythmia circuit, and the dynamic probe allowed us to identify the most relevant electrogram sites for ablation.

**CASE 2**

**History**

The patient is a 72-year-old woman with symptomatic persistent atrial fibrillation first documented five years ago. She has a history of systemic hypertension controlled on a combination of metoprolol and losartan, and is known to have moderate pulmonary hypertension. The patient failed to tolerate dofetilide because of torsades de pointes ventricular tachycardia, and her AF was resistant to flecainide and dronedarone. She underwent electrophysiologic assessment and catheter ablation four years ago.

At the index ablation, radiofrequency pulmonary vein isolation resulted in sinus rhythm, but atrial fibrillation spontaneously recurred. After extensive ablation of complex fractionated atrial electrograms, sinus rhythm was restored. She was treated with flecainide for three months, and was free of clinical arrhythmia until 3 months before the current ablation. Her arrhythmia recurrence was with atrial fibrillation and atypical atrial flutter, resistant to flecainide and dronedarone, and she was scheduled for re-do catheter ablation.

**Procedure**

The details of preparation and left atrial access were identical to case 1. The patient was in atrial fibrillation at the beginning of the case, and the initial left atrial anatomy was collected during atrial fibrillation. This revealed low voltages in the pulmonary veins. Ablation of complex fractionated atrial electrograms in the interatrial septum and anterior to the right superior pulmonary vein resulted in an atypical atrial flutter, and an electroanatomic map was consistent with a mitral flutter. A linear lesion was constructed between the left inferior pulmonary vein and the mitral annulus, and lesions were also made in the coronary sinus adjacent to the inferior end of the line. Atrial flutter continued, so a new activation map of the left atrium was constructed (Figure 8).
The map was derived from more than 30,000 electrograms, and was constructed over 23 minutes. There was a narrow band of activation across the mitral isthmus just inferior to the left inferior pulmonary vein (Figure 8a). Activation passed superiorly up the Coumadin ridge, but also retrograde to collide with the mitral isthmus line (Figures 8b & 8c), indicating that there was block across the remainder of the mitral isthmus line. The circuit was completed with activation across the LA roof and inferiorly down the posterior LA wall (Figures 8d–8f). Detailed mapping was performed endocardially around the inferior pole of the left inferior pulmonary vein, but revealed only very low voltages, and ablation was ineffective. The ablation catheter was advanced epicardially to the vein of Marshall, and ablation resulted in termination of the tachycardia. Mitral isthmus block was later demonstrated by pacing maneuvers.

Comment
When left atrial flutters fail to terminate despite ablation in what should be the proper place, identification of deficiencies in linear lesions or slight modifications in the arrhythmia circuit is paramount. Using high-density contact mapping, we were able to assess the integrity of the endocardial line, identify the gap, and use the map to guide successful epicardial ablation.

CASE 3
History
The patient is a 71-year-old man with a three-year history of persistent atrial fibrillation. His only structural heart disease is hypertension. The patient was randomized to the catheter ablation arm of the CABANA trial, and underwent his index ablation three years ago. He was in persistent atrial fibrillation, which continued after pulmonary vein isolation. He underwent left atrial posterior wall isolation with linear lesions across the LA roof and low posterior wall, and after completion of these lesions he converted to a mitral atrial flutter. A mitral isthmus lesion was constructed from the left inferior pulmonary vein to the mitral annulus and after completion of the linear lesion with burns in the coronary sinus, the patient returned to sinus rhythm. After return to sinus rhythm, pacing maneuvers confirmed mitral annular block, pulmonary vein, and posterior wall isolation. The patient was treated with dofetilide for 8 weeks postoperatively and initially was arrhythmia free. He began to notice recurrent palpitations 6 weeks before the current procedure, and atypical atrial flutter was documented at symptom times.

Procedure
The details of preparation and left atrial access were identical to case 1. The patient was in atrial flutter at the onset of the procedure, and an electroanatomic map revealed recurrent mitral flutter with a defect in the mitral isthmus line. This was ablated and sinus rhythm was restored. Mitral isthmus block was confirmed by pacing maneuvers. With rapid atrial pacing, a new, faster, atrial tachycardia was initiated. A second electroanatomic map was constructed (Figure 10). This confirmed mitral isthmus block (not shown). There was a focal, atrial tachycardia located on the anterior LA wall, close to the fossa ovalis. The mechanism was apparently microreentry, because activation appeared to rotate around a central core (Figure 10a). Electrical activity recorded from the center of the reentrant rotor was very low amplitude and broad. (Figure 10b). The tachycardia was interrupted with a few radiofrequency lesions and after restoration of sinus rhythm, no atrial tachycardias could be induced despite aggressive pacing.

Comment
Focal tachycardias are infrequently encountered after ablation of persistent atrial fibrillation. High-density contact mapping was able to identify the source, and also demonstrate the probable mechanism.
Using Rhythmia™ for AF Ablation and Pulmonary Vein Isolation

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The creation of a durable, inexcitable dense scar (IDS) is paramount to the long-term success of any ablation. Permanent electrical isolation of pulmonary veins (PVs) and other target areas in the left and right atria still remains a challenge, and may undermine the success of ablation outcomes for atrial fibrillation (AF). Reconnection at an excitably dormant area may be a mechanism for recurrent AF or other atrial arrhythmias. High-output pacing with non-capture is considered by many to be the gold standard for defining IDS. Recently, the Penn group has been able to correlate atrial IDS with a range of bipolar voltages achieved on a CARTO® 3 system using a circular Lasso catheter. Validating lesion sets for inexcitability after thorough ablation may translate into more durable electrical isolation and thus improve outcomes. The Rhythmia™ Mapping System is capable of producing rapid, dense, and high-resolution voltage maps with V-map™ after ablation is performed. In our experience, this has become an indispensable part of AF ablation.

Our work flow for validation of lesions in AF ablation is represented by a few case studies. A prevoltage map is created with the Rhythmia™ Mapping System in sinus rhythm, while pacing at 600 milliseconds from the proximal coronary sinus catheter (Figures 1a & 1b). Pacing at this cycle length expedites the collection of information, typically over a slower sinus rate. In just a few minutes, over 13,000 EGMs were collected throughout the left atrium and PVs by the Orion’s 64 electrodes. If voltage mapping is done in AF, cycle-length criteria on the Rhythmia™ system must be disabled. Sinus or paced voltage maps will vary when compared to voltage maps created in AF. For this reason, we often avoid creating voltage maps in AF.

The Boston Scientific MiFi™ radiofrequency 8-mm ablation catheter is often used in conjunction with the Orion™ catheter to minimize ablation of far field signals commonly noted on the conventional tip electrode, as well as on the equatorial splines. Additionally, pacing maneuvers (especially from the left atrial appendage) are often necessary to sort out near field versus far field signals. Bipolar voltage lower and higher values are set to 0.1mV and 0.3mV, respectively. Using these cut-off values, we assign purple color to viable tissue and red or gray colors to correlate with IDS. The Rhythmia™ system offers recordable voltage activity as low as 0.01 mV (the baseline noise level for the Rhythmia™ system). Although the values assigned to red are considered to be IDS, our goal for the PVs and posterior wall is to see gray color covering those areas upon remap. Of course, this goal may be limited by the proximity of the esophagus to the posterior wall. It may be difficult to reduce voltage to other areas such as the left atrial roof and mitral isthmus due to tissue thickness, and thus may not be recommended as a goal.

The remap feature of the Rhythmia™ platform allows for high-density acquisition of new points on a previous anatomic shell. Figure 2 shows IDS around the PVs and the posterior wall between the PVs after successful ablation.
Figure 1a: Pre Ablation Voltage Map of Pulmonary Veins.

Figure 1b: Post Ablation Voltage Map of Pulmonary Veins.
The small, colored dots represent individual electrode recordings. It is important to see a high sampling size of these dots in each area to increase the accuracy of the findings. If PV isolation cannot be readily achieved, an activation map can quickly be done with the Orion™ catheter. Figure 3 illustrates a gap in the left inferior PV while pacing the coronary sinus. Similarly, gaps can be mapped along the roof line to guide further ablation sites (figure 4). During the course of a typical AF ablation, many maps may be created on the same initial anatomical shell. The added time to the case with each remap is minimal, and the benefits are to ensure lesion validation in a way that no other system can provide.

CONCLUSION

Using the Rhythmia™ mapping system to perform AF ablation is an effective, rapid way to aid in PVI and distinguish between IDS and excitable or viable tissue. Because the Orion™ catheter basket can be collapsed and expanded, it can navigate into PV branches as easily as a standard ablation catheter. Once in the PV, it can be expanded or collapsed to touch the wall of the PV. The Lasso® has been shown to underrecognize PV signals when compared to the Orion™. In addition to covering more territory, the Rhythmia™ creates a high-fidelity map with 2-mm density of thousands of contact electrogram points. This minimizes extrapolation of information and thus increases the fidelity of the map. vMap™ is the new standard in lesion assessment technology. It allows the user to quickly create high-resolution validation maps multiple times during the procedure, clearly assess electrical gaps, and verify lesion integrity. The Rhythmia™ mapping system is a powerful, effective tool. When used properly, it can help clinicians to fully achieve an endpoint and may improve clinical outcomes for AF ablation.

References


Mapping and Ablation of Atrial Flutter after Cardiac Surgery with Rhythmia™ Electroanatomic Mapping System

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Cavotricuspid isthmus-dependent atrial flutter is the most commonly encountered flutter in a patient with previous cardiac surgery. However, when mapping, it is not uncommon to find a “double-loop” or a “figure of 8” atrial flutter in the right atrium of these patients. The challenge remains to define the circuit in the lateral right atrium after cavotricuspid isthmus is ablated and the tachycardia continues, albeit with activation or cycle-length change, generally implying continuation of the second arrhythmia circuit. The newly introduced Boston Scientific Rhythmia™ Mapping System simplifies activation mapping during such macroreentrant tachycardia when entrainment mapping is unreliable or not feasible.

CLINICAL CASE

A 76-year-old female with a history of asthma, hypertension, a previous TIA, and mitral valve repair without left atrial maze procedure or appendage ligation in 1994 presented with symptomatic atrial flutter of unknown duration. She had been on Coumadin chronically with an INR between 2-3. Her CHADS Vasc score was 5. The presenting 12-lead ECG showed common right atrial flutter. The patient was recommended to undergo mapping and RF ablation of the atrial flutter, which she accepted. Rhythmia™ mapping was used for this patient.

She was taken to the EP lab, where under conscious sedation a duo-decapolar diagnostic catheter was inserted in the coronary sinus with the proximal portion of the catheter hugging the anterolateral right atrium. The atrial activation was noted to be high to low in the right atrium, and proximal to distal in the coronary sinus as shown in Figure 1. The Orion™ Mini-Basket Catheter was inserted, and activation mapping was performed in the right atrium after anti-coagulating the patient with heparin (ACT > 300). A total of 11,018 activation points were taken in 17 minutes, 22 seconds of Rhythmia™ mapping. A large area of vertical scar was noted in the posterolateral right atrium, presumably from the prior mitral valve surgery (Figure 2 inset). The flutter cycle length was 275 milliseconds (ms) with variable ventricular activation. The flutter was diagnosed as a counter-clockwise, cavotricuspid, isthmus-dependent right atrial flutter with a second loop going around the crista terminalis, creating a double-loop reentry (Figure 2). Using an irrigated, 4-mm RF ablation catheter, a contiguous point-by-point ablation line was created at the CTI from the distal end at the tricuspid annulus to the IVC isthmus junction. Ablations were done in a power-controlled mode at 25-30 watts with abatement of bipolar EGMs.

With completion of the CTI ablation line, the atrial flutter
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Cy\text{cle length essentially remained the same. However, the activa-}
\text{tion sequence noted on the duo-decapolar catheter changed (Figure 3). Activation mapping was performed again using the Orion™ Mini-Basket Mapping Catheter (8,988 points in 8 minutes, 38 seconds), confirming the flutter circuit to be the continuation of the ‘second loop’ of the original “double-loop” flutter (Figure 4). With high-density Rhythmia™ mapping, it was easily discernible that the isthmus for the circuit was the tissue between the crista terminalis and the posterolateral scar. Slow conduction was noted, spanning the majority of the atrial diastole (Figure 4 inset). With a single RF ablation, the flutter cycle length lengthened and broke with resumption of normal sinus rhythm.}

Thereafter, bidirectional block across the CTI was confirmed using standard differential pacing maneuvers. The groin sheaths were removed. The patient tolerated the procedure without any complications, and has had no recurrence of atrial flutter since the ablation.

To the operator’s advantage, there is minimal, if any, manual re-annotation required of the acquired activation data points.

Figure 2: RAO and LAO projections of the right atrium on the Rhythmia™ Mapping System, depicting flutter activation map showing the two circuits comprising the ‘double-loop’ reentry circuit. The inset shows right posterior oblique (RPO) view of the right atrium depicting the extent of the scar. TA: tricuspid annulus; IVC: inferior venacava; SVC: superior venacava; CT: crista ter-
minalis; RAO: right anterior oblique projection; LAO: left anterior oblique projection; RPO: right posterior oblique.

Figure 3: Intracardiac EGMs showing distal to proximal coronary sinus activation, with completion of the CTI abla-
tions consistent with continuation of the second arrhythmia circuit of the ‘double-loop’ reentry, which is now activating the left atrium via the Bachman’s bundle, rather than from the proximal to distal coronary sinus due to CTI block.
DISCUSSION

For mapping of arrhythmias, Boston Scientific’s Rhythmia™ Mapping System is the “new kid on the block.” The use of the proprietary, mini-basket Orion™ catheter allows fast acquisition of a large number of data points rapidly generating accurate, coherent, high-resolution, 3-dimensional activation arrhythmia maps.1,2 To the operator’s advantage, there is minimal, if any, manual re-annotation required of the acquired activation data points.2 Furthermore, the noise level in the Rhythmia™ Mapping System is very low, which helps in meaningful reconstruction of the arrhythmia circuits, especially in low-amplitude areas of scar.1

The high resolution allows accurate and sharp demarcations of the acquired activation times, allowing precise delineation of the arrhythmia circuit with associated lines of block and slow activation.1 This allows the operator to visually discern the most vulnerable part of the circuit, where minimal amount of ablation will interrupt the circuit and treat the scar-related macroreentrant arrhythmia.

With the above-mentioned advantages, the use of the Rhythmia™ Mapping System is gaining popularity in mapping both atrial and ventricular arrhythmias.3,4 However, only time will tell whether it will match (or surpass) the sophistication of the established market leaders in electroanatomic mapping of arrhythmia. Nonetheless, the competition created by its introduction should spur innovation in electroanatomic mapping, which will ultimately benefit our patients.

References
Use of a Force-sensing Ablation Catheter with the Rhythmia™ Mapping System to Facilitate Successful Ablation of Atrial Flutter

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A 61-year-old man was referred for evaluation and catheter ablation of atrial flutter. He had a history of mitral valve regurgitation and atrial fibrillation and underwent mitral and tricuspid valve repairs, left-atrial maze ablation, and left atrial appendage ligation six years prior. The patient also had a prior catheter ablation for atrial flutter at another institution five years prior – the details of which were not available at the time – and external cardioversion for atrial fibrillation 9 months prior. He presented to the outpatient clinic with symptomatic tachycardia. A 12-lead electrocardiogram demonstrated atrial flutter with a subtle change in flutter-wave morphology and cycle length after the fifth QRS complex (Figure 1). He was receiving medical management with beta-blocker therapy and apixaban for therapeutic anticoagulation. After discussion of multiple management options, he decided to proceed with repeat catheter mapping and ablation.

The patient arrived to the electrophysiology laboratory in atrial flutter. We decided to proceed with electroanatomical mapping using the Rhythmia™ Mapping System. Additionally, a second mapping system was enabled in order to take advantage of the contact force-enabled ablation catheter technology.

Appropriate femoral venous access was obtained, and a Blazer™ Dx-20 bidirectional duodecapolar diagnostic catheter was advanced into the right atrium, with the proximal 10 electrodes positioned around the lateral tricuspid annulus, and the distal 10 electrodes positioned within the coronary sinus. Initial intracardiac electrograms demonstrated counterclockwise activation around the tricuspid annulus and proximal-to-distal activation along the coronary sinus. There was subtle alternation of the atrial cycle length between 370 and 380 milliseconds (ms), and 67% of the cycle length was accounted for using available right atrial electrodes. After a goal-activated clotting time (ACT) of >300 seconds was achieved with heparin bolus and infusion, the IntellaMap Orion™ high-resolution mini-basket mapping catheter was advanced to the right atrium for high-density activation and voltage mapping.

Over 28 minutes of mapping, 33159 electrograms were recorded in the right atrium within 4 mm of the projected surface, and 22294 electrograms were recorded within 2 mm of the surface using the Rhythmia™ three-dimensional Mapping System (Figure 2). The voltage map demonstrated a narrow region of scar traversing from the posterior right atrium, across the lateral wall toward the tricuspid valve annulus around the 8:00 position. The corresponding propagation map showed counterclockwise activation of the right atrium around the tricuspid valve annulus with intact conduction.
across the cavo-tricuspid isthmus, but significant conduction delay across the lateral low-voltage area. There was a narrow zone of intact conduction at the annular aspect of the lateral wall scar. Split potentials greater than 120 ms were noted more posteriorly along the scar, with narrower splits near the annulus, consistent with an incomplete line of conduction block.

While it was anticipated that arrhythmia termination could be achieved with cavo-tricuspid isthmus ablation, the decision was made to proceed with ablation at the lateral aspect of the tricuspid annulus to complete the line of partial conduction block. Given the difficulty that is sometimes encountered in achieving consistent catheter contact at that location, we chose a force-sensing ablation catheter for radiofrequency delivery. The output from the force-sensing ablation catheter was split to both a third-party mapping system and to the Rhythmia™ Amplifier (Figure 3). The second system was positioned at the bedside in direct view of the primary operator. The Rhythmia™ Amplifier was connected to both the CardioLab electrophysiology recording system

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Figure 2: Baseline right atrial activation (left) and voltage (right) maps, demonstrating scar along the lateral wall corresponding to a line of partial conduction block, with a small area of preserved voltage and conduction near the tricuspid valve annulus.

Figure 3: Simplified schematic depicting connections to force-sensing ablation catheter system and Rhythmia™ products.
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(GE Healthcare, Wauwatosa, WI) and to the Rhythmia™ Workstation, which was situated in the control room. This setup allowed the operator to directly visualize contact force data (Figure 4) while having electrogram and mapping data available through CardioLab and Rhythmia™ respectively.

A lesion set was delivered from the lateral tricuspid valve annulus back to the previously described lateral wall scar, while contact force data was monitored. Energy was applied at 20–35 W, targeting electrogram attenuation, 10–12 ohm impedance drops, and force-time integral (FTI) of 400 gram-seconds at each location. No significant change in atrial flutter cycle length was noted. Entrainment maneuvers were subsequently used to confirm cavotricuspid, isthmus-dependent, counter-clockwise right atrial flutter. A second lesion set was delivered along the cavotricuspid isthmus, with termination of atrial flutter to sinus rhythm. A more focal map of the isthmus, with 4633 electrograms collected over 4 minutes, allowed for rapid localization of areas of breakthrough conduction. Additional lesions were delivered to achieve rate-independent, bidirectional conduction block across the cavotricuspid isthmus. This persisted through a 45-minute waiting period.

The novel aspect of this procedure was the use of a force-sensing ablation catheter. Usage was monitored through the EnSite™ system for real-time contact force feedback with the Rhythmia™ high-density mapping system. Major benefits of both systems were appreciated. The high-density voltage and propagation maps, for example, improved characterization of the existing lateral right atrial scar, which was potentially contributing to the subtle variation in atrial cycle length and perhaps even to the change in flutter-wave morphology noted on the initial 12-lead EKG. In a patient with prior surgical and catheter ablation, such a scar with incomplete conduction block may have served as the substrate for future atrial arrhythmias if we had addressed only the cavotricuspid isthmus. Additionally, the Rhythmia™ system allowed for clear delineation of areas of conduction breakthrough along the cavotricuspid isthmus after flutter termination, facilitating efficient delivery of additional lesions to achieve conduction block. Similarly, the contact force feedback provided by the EnSite™ system via the force-sensing ablation catheter potentially improved both safety and efficacy of radiofrequency delivery.

The Rhythmia™ Mapping System generates complete, detailed electroanatomical maps in short periods of time and allows for impedance-based tracking of any standard ablation catheter. One current limitation compared with other commonly used mapping systems is the lack of contact force integration and feedback. The techniques utilized during a successful characterization and ablation of atrial flutter in a complex patient represent a novel method for incorporating ablation catheter contact force data into a high-density activation map.

The techniques utilized during a successful characterization and ablation of atrial flutter in a complex patient represent a novel method for incorporating ablation catheter contact force data into a high-density activation map.

Figure 4: Contact force display available on the force-sensing system during ablation catheter mapping and radiofrequency delivery.
Mapping and Ablation of an Atypical Left Atrial Flutter in a Patient with a Mechanical Mitral Valve Repair

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Atypical arrhythmias—including atypical atrial flutter and focal atrial tachycardia—frequently occur following cardiac valve surgery or atrial fibrillation ablation. Depending on the type of ablation, up to 50% of patients may develop an atrial tachyarrhythmia. Data on the rates of atypical atrial flutter following mitral valve surgery are not well characterized, but atrial fibrillation is very common following cardiac surgery.

As opposed to cavotricuspid isthmus-dependent typical atrial flutter originating in the right atrium, atypical atrial flutter frequently originates from the left atrium. The most common flutter circuit is a perimital circuit rotating around the mitral valve, but circuits may also be roof dependent or originate on the intraatrial septum. Multiple circuits may be present, creating a unique challenge when mapping and ablating these arrhythmias. New, automated high-density 3D mapping systems may enhance the ability to localize and ablate these complex arrhythmias. We report the use of the Rhythmia™ Mapping System to successfully map and ablate an atypical left atrial flutter in a patient with a mechanical mitral valve.

CASE REPORT

A 63-year-old female presented with shortness of breath. An electrocardiogram showed atypical atrial flutter with a rapid ventricular response. She had a history of a mechanical mitral valve replacement 24 years ago, and atypical atrial flutter for the past 2 years. She had not had a prior Maze surgery or left atrial ablation. An echocardiogram showed a normal ejection fraction and normal function of her mechanical valve. A prior electrophysiology study six months prior demonstrated left-sided atrial flutter, at which time she was cardioverted and started on amiodarone. Despite medication, she had continued to have symptomatic recurrences of her arrhythmia, and was referred for definitive management with left-sided catheter ablation.

High-density automated mapping systems such as Rhythmia™ can be of use in these cases to accurately identify areas of scar and critical zones of slow conduction.

The patient was taken to the electrophysiology lab for mapping and ablation of her arrhythmia. After obtaining venous access, a 20-pole catheter was placed in the coronary sinus, and a double transseptal puncture was performed. An irrigated tip ablation catheter and the Orion™ Mapping Catheter were advanced into the left atrium.

At the start of the procedure, the patient was in atrial flutter with a tachycardia cycle length of 235 milliseconds. Using the Orion™ mapping catheter, activation and voltage mapping were performed within the left atrium. Mapping of the flutter took 36 minutes. The automated collection process allowed us to collect 22,297 individual EGMs from 2268 heartbeats. The map demonstrated a left-sided atrial flutter originating near a small area of scar on the posterior wall of the left atrium (figure 1, movie 1). A zone of slow
conduction — most likely a critical isthmus of the flutter circuit — could be seen adjacent to the right inferior pulmonary vein. The high number and density of EGMs obtained allowed us to easily localize the origin of the flutter circuit.

After mapping, we proceeded with ablation of the atrial flutter. Ablation was started in the region of scarring and slow conduction. Within 1 minute of starting ablation, the flutter terminated and was no longer inducible (Figure 1, pink dot). In addition to ablating the atrial flutter, we isolated the pulmonary veins with bilateral, wide-area circumferential ablation. The Rhythmia™ system was used to confirm entrance block and isolation of the pulmonary veins by making a voltage map of the left atrium post ablation (Figure 2). As we had already built an anatomical shell of the left atrium, we were able to acquire this second map much more quickly. This map contained 8135 EMGs from 419 beats and was acquired in 12 minutes. While making the voltage map, pacing from the Orion™ catheter within the pulmonary veins was performed to demonstrate exit block.

There were no complications. The total fluoroscopy time was 13.7 minutes. The total procedure time was 189 minutes. The patient was monitored overnight and discharged home the next day. Seven months post ablation, the patient was evaluated and is doing well. She is off of antiarrhythmic drugs, and has had no recurrence of her atrial flutter.

DISCUSSION
Iatrogenic atypical atrial flutters are often seen following both cardiac surgery and atrial fibrillation ablation. Mapping and ablation of these arrhythmias is challenging due to the presence of multiple circuits. Although there is an elevated risk of complications, patients with mechanical heart valves can and do undergo successful left atrial ablations. High-density automated mapping systems such as Rhythmia™ can be of use in these cases to accurately identify areas of scar and critical zones of slow conduction. We report the successful ablation of a persistent left atrial flutter in a patient with a mechanical mitral valve using the Rhythmia™ Mapping System.

References
The Rhythmia™ Mapping System and accessories are intended for catheter-based atrial and ventricular mapping. The mapping system allows real-time visualization of cardiac catheters as well as display of cardiac maps in a number of different formats. The acquired patient signals, including body surface ECG and intracardiac electromgrams, may also be recorded and displayed on the system’s display screen.

CONTRAINDICATIONS

There are no known contraindications.

WARNINGS AND PRECAUTIONS

- Do not operate the Rhythmia Mapping System near flammable anesthetics. System operation near flammable anesthetics may cause an explosion that could cause injury or death to the patient or user.
- All devices that are connected to the Rhythmia Mapping System must meet IEC 60601-1-1 requirements and any other relevant safety standards. When connected to other equipment, the system must meet the IEC 61010-1 Safety standards. The use of the Rhythmia Mapping System with accessories and devices that do not comply with relevant standards may reduce the safety of the system, cause equipment damage or system malfunction, or harm to the patient or user.
- Only stimulators that are certified for IEC 60601 should be used with the Rhythmia Mapping System.
- Do not connect life-sustaining pacing through the Rhythmia Mapping System. The system is not intended to provide life-sustaining therapy and should not be used as such. In case of need for emergency pacing, or any failure of stimulator routing, directly connect to the desired pacing channel to the stimulator.
- The Rhythmia Mapping System is only designed to route the stimulation signal to the desired channel. To start or stop stimulation, always use the controls on the external stimulator.
- Use the Rhythmia Mapping System only with one of the following RF ablation generators: Maestro 3000™, Stockert™, or IB™. Do not use the system with other RF ablation generators. Compatibility with other RF ablation generators has not been demonstrated.
- Do not apply RF energy larger than 150W to ablation catheters that are connected to the Maestro 3000 RF generator and the Rhythmia Mapping System.
- Do not apply RF energy larger than 70W to ablation catheters that are connected to the Stockert RF generator and the Rhythmia Mapping System.
- Do not apply RF energy larger than 50W to ablation catheters that are connected to the IBI RF generator and the Rhythmia Mapping System.
- To reduce the risk of electrical shock or equipment damage, do not clean the Rhythmia Mapping System when it is plugged in, turned on, or connected to a patient. Cleaning the system while it is in use or connected to a power source may cause an electrical shock that could cause injury or death to the patient or user.
- To reduce the risk of electrical shock, assure that any ECG cables and electrodes are not in contact with any other conductive parts, including ground.
- To reduce the risk of electrical shock during defibrillation, assure that the exposed connector tips on the ECG output box are covered at all times with the protective, non-conductive material provided with the ECG output box. Do not use the ECG output box if the protective cover is damaged (see ECG Output Box).
- The system generates electrical impedance fields as part of its normal operation. Do not use other systems that also generate electrical impedance fields in the same procedure, as this may interfere with the system’s normal operation and reduce the quality of catheter localization, and signals.

Magnetic Localization System

- Do not operate the Localization Generator within 200 mm of installed cardiac implantable electronic devices (CIED). Doing so may affect pacing, temporarily suspend tachycardia therapy delivery, or lead to patient discomfort.
- To minimize the risk of electrical shock, connect the Signal Station only to supply mains with a protective ground (earth) connection. Use only a functioning, properly tested supply main with protective ground (earth) to power the Rhythmia Mapping System.
- The use of a faulty, ungrounded supply main increases the risk of electrical shock and system malfunction.
- To minimize the risk of electrical shock, prior to using the Rhythmia Mapping System, connect the equipotential socket (located on the Signal Station rear panel) to a common ground. This connection grounds the Rhythmia Mapping System and must remain connected at all times (see Signal Station Seablet). If these cables are within 30mm or less, particularly if they are parallel to each other, inaccurate tracking or "noisy" signals may occur.
- Do not coil the Localization Generator cable. Doing so can disturb the magnetic field of the Localization Generator, which may lead to inaccurate tracking.
- Do not use the Magnetic Localization System in the presence of other magnetic fields or large metal objects. Doing so may lead to inaccurate tracking.

Localization Generator

- Manually disabling the Localization Generator disables all catheter visualization and localization capabilities, including impedance tracking.
- Do not place the Localization Unit (SCU) or Sensor Interface Unit (SIU) within 1m of the Localization Generator. Doing so may lead to inaccurate tracking.
- Do not place cables used with the Rhythmia Mapping System within 30mm of the Localization Generator cable. Kinks and sharp bends can damage the cables, which may cause system malfunction.
- To minimize the risk of damage, store unused system cables in a clean, dry, and secure location, consistent with storage guidelines (see Equipment Storage & Transporting in the DFU).

Electrical

- Never use ungrounded electrical outlets to power any system components. Do not use extension cords or adapters for ungrounded outlets. Using ungrounded outlets, extension cords, or adapters may cause equipment damage, system failure or malfunction.

Body Surface Electrodes

- Use care when attaching the body surface electrodes to lead connectors. To minimize the risk of electric shock, make sure that electrodes and lead connectors do not contact one another or contact ground.
- To prevent low quality signals from body surface electrodes, properly prepare the skin prior to attaching the electrodes. Do not use excessive gel as this may lead to shorts between different electrodes.
- Environmental
- Do not immerse any cable connectors in water or liquid. Immersion in water or liquid may damage connectors, which may cause system malfunction.

Magnetic Localization System

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- Do not place the Localization Unit (SCU) or Sensor Interface Unit (SIU) within 1m of the Localization Generator. Doing so may lead to inaccurate tracking.
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Localization Generator

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During the Procedure

- To reduce catheter configuration mistakes, when connecting catheters to the system, always verify the signals by reviewing the signal display and recording system to ensure correct configuration of catheter electrodes to displayed channels.
- To ensure correct clinical decisions, use fluoroscopy, ultrasound, pace mapping or other visualization techniques to verify mapping results and catheter position. Always compare the anatomical map to the patient’s expected anatomy.
- When a catheter localization error is encountered, use fluoroscopy or other visualization techniques to verify catheter location.
- Imported geometrical shells should only be used as a reference, for example to identify anatomical features in advance of mapping. Use other visualization tools, such as fluoroscopy or echocardiography to verify catheter location.
- During the mapping procedure, do not disconnect the Localization Unit from the Signal Station and/or the Localization Generator from the Localization Unit. Ensure caps are installed on Localization Unit SIU connection ports that are not in use. (Rev A)
RHYTHMIA™ MAPPING SYSTEM
EXPERIENCE HIGH DEFINITION, HIGH RESOLUTION MAPPING.