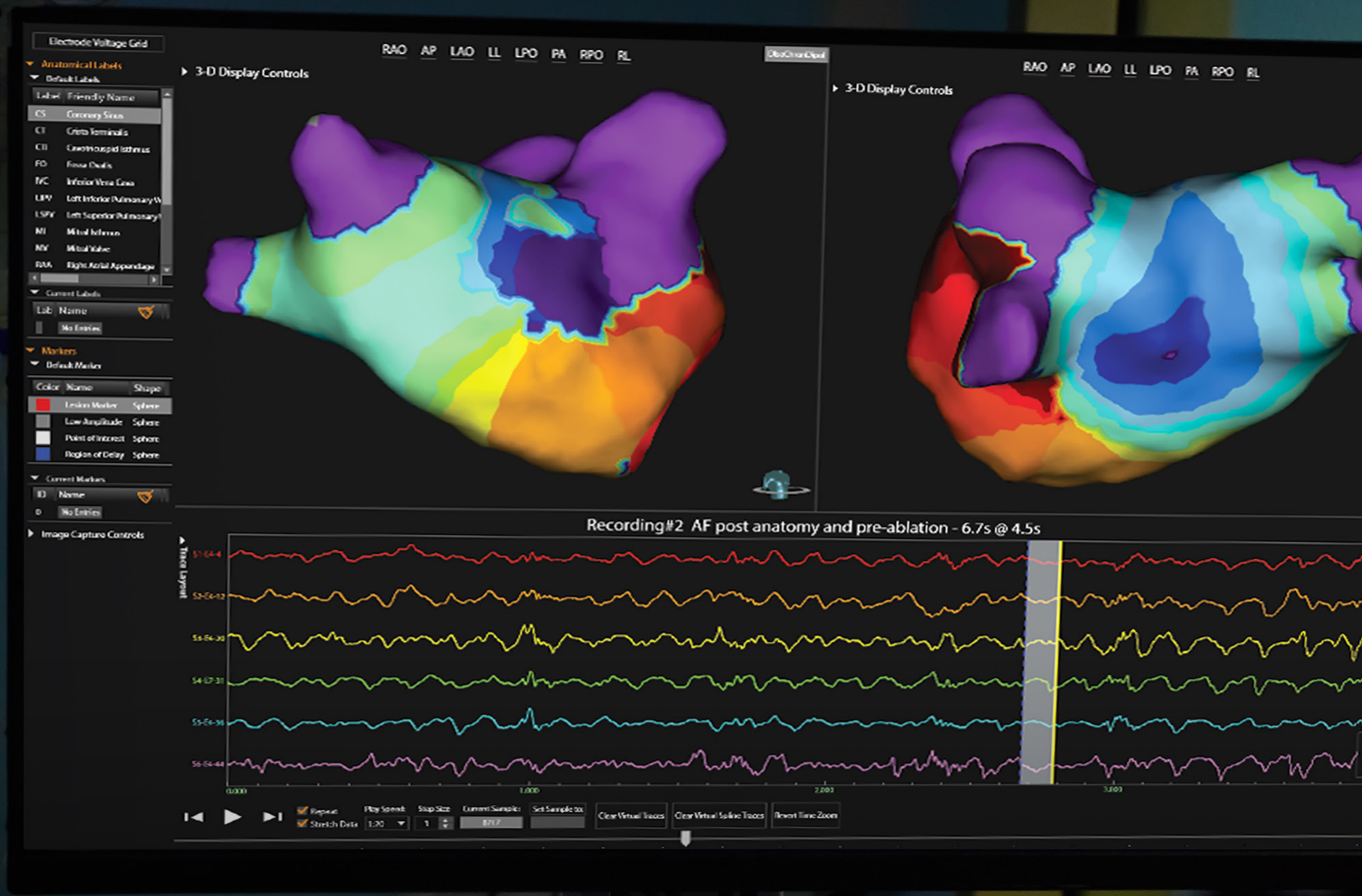

Acutus Medical Clinical Compendium

2019-2020

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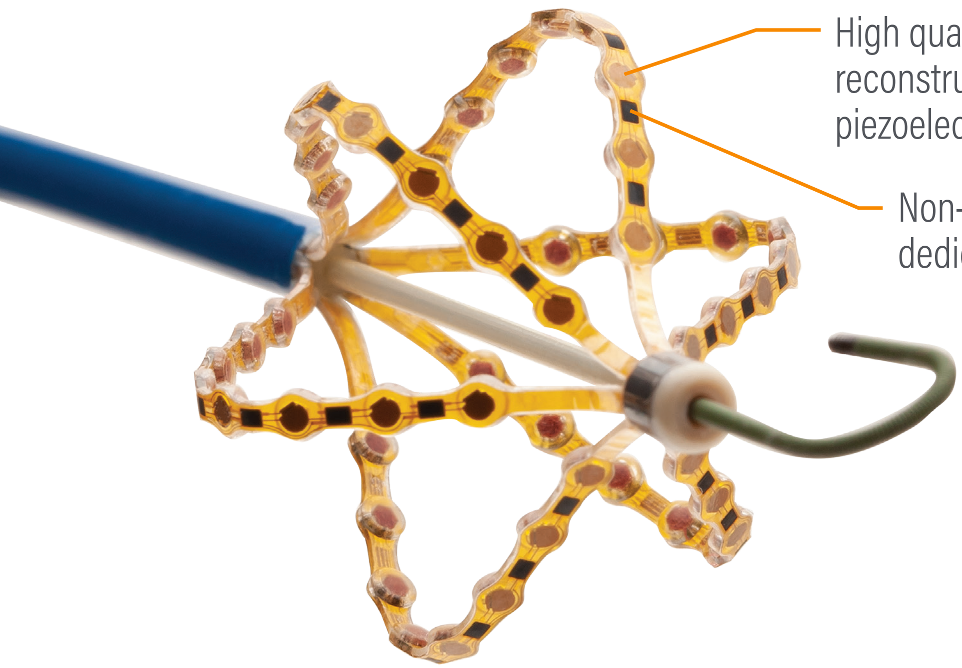

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- Improved handling[1] with enhanced torquability
- Enhanced deliverability with a .035″ guidewire

CONTENTS

PUBLICATIONS

ACQMAP® CLINICAL OUTCOMES

CASE STUDIES

ATRIAL FIBRILLATION MECHANISMS

CONTENTS (CONT.)

PUBLICATIONS

Diverse Activation Patterns during Persistent Atrial Fibrillation by Non-Contact Charge-Density Mapping of Human Atrium

Journal of Arrhythmia. 2020;DOI:10.1002/joa3.12361.

Rui Shi[1,2], Zhong Chen[2], Charlie Butcher[2], Junaid AB Zaman[2], Vennela Boyalla[2], Yi Kan Wang[3], Omar Riad[2], Anitha Sathishkumar[2], Mark Norman[2], Shouvik Halder[2], David G Jones[2], Wajid Hussain[2], Vias Markkides[2], Tom Wong[2].

[1] The First Affiliated Hospital of Xi'an Jiaotong University, Xi'an, China

[2] The Royal Brompton and Harefield NHS Foundation Trust, Imperial College, London, UK

[3] Auckland Bioengineering Institute, University of Auckland, Auckland, New Zealand

BACKGROUND: Global simultaneous recording of atrial activation during atrial fibrillation (AF) can elucidate underlying mechanisms contributing to AF maintenance. A better understanding of these mechanisms may allow for an individualized ablation strategy to treat persistent AF. The study aims to characterize left atrial endocardial activation patterns during AF using non-contact charge-density mapping.

METHODS: Twenty-five patients with persistent AF were studied. Activation patterns were characterized into three subtypes: (i) focal with centrifugal activation (FCA); (ii) localized rotational activation (LRA); and (iii) localized irregular activation (LIA). Continuous activation patterns were analyzed and distributed in 18 defined regions in the left atrium.

RESULTS: A total of 144 AF segments with 1068 activation patterns were analyzed. The most common pattern during AF was LIA (63%) which consists of four disparate features of activation: slow conduction (45%), pivoting (30%), collision (16%), and acceleration (7%). LRA was the second-most common pattern (20%). FCA accounted for 17% of all activations, arising frequently from the pulmonary veins (PVs)/ostia. A majority of patients (24/25; 96%) showed continuous and highly dynamic patterns of activation comprising multiple combinations of FCA, LRA, and LIA, transitioning from one to the other without a discernible order. Preferential conduction areas were typically seen in the mid-anterior (48%) and lower-posterior (40%) walls.

CONCLUSION: Atrial fibrillation is characterized by heterogeneous activation patterns identified in PV-ostia and non-PV regions throughout the LA at varying locations between individuals. Clinical implications of individualized ablation strategies guided by charge-density mapping need to be determined.

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Novel Non-Contact Charge Density Map in the Setting of Post-Atrial Fibrillation Atrial Tachycardias: First Experience with the Acutus SuperMap Algorithm.

Journal of Interventional Cardiac Electrophysiology – https://doi.org/10.1007/s 10840-020-00808-9.

Robbert Ramak, Gian-Battista Chierchia, Gaetano Paparella, Cinzia Monaco, Vincenzo Miraglia, Federico Cecchini, Antonio Bisignani, Joerelle Mojica, Maysam Al Housari, Dimitrious Sofianos, Shuichiro Kazawa, Ingrid Overeinder, Gezim Bala, Erwin Stroker, Juan Sieira, Thiago Guimaraes Osorio, Pedro Brugada, Carlo de Asmundis. Universitair Ziekenhuis Brussel, Brussels, Belgium

PURPOSE: The purpose of this study was to evaluate the safety and feasibility of the new high-resolution mapping algorithm SuperMap (Acutus Medical, CA, USA) in identifying and guiding ablation in the setting of regular atrial tachycardias following index atrial fibrillation (AF) ablation.

METHODS: Seven consecutive patients who underwent a radiofrequency catheter ablation guided by the novel non-contact chargedensity (CD) SuperMap for atrial tachycardia were prospectively enrolled in our study.

RESULTS: Arrhythmogenic substrate was identified in all seven patients. Mean number of EGM per map was 5859.7 ± 4348.5 points. Three patients (43%) exhibited focal tachycardia mechanisms in the left atrium, alternating from anteroseptal right superior pulmonary vein (RSPV), posterior in proximity of left inferior pulmonary vein (LIPV), and interarial septum in proximity of fossa ovalis, respectively. Four patients exhibited macroreentrant mechanism. In 3 of these patients, SuperMap detected mitral isthmus-dependent flutters with tachycardia cycle lengths of 240, 270 and 420ms, respectively. In one patient, themechanism was a macroreentrant tachycardia with the critical isthmus located between the crista terminalis and atriotomy. The mean ablation time (min) was 18.2 ± 12.5 and the mean procedural duration time was 56.4 ± 12.1 min. No minor or major complications occurred.

CONCLUSION: The novel high-resolution mapping algorithm SuperMap proved to be safe, fast, and feasible in identifying and guiding ablation in the setting of regular atrial tachycardias following index AF ablation.

Validation of Dipole Density Mapping during Atrial Fibrillation and Sinus Rhythm in Human Left Atrium

J Am Coll Cardiol EP 2020;6:171-81

Shi R, Parikh P, Chen Z, Angel N, Norman M, Hussain W, Butcher C, Haldar S, Jones DG, Riad O, Markides V, Wong T. First Affiliated Hospital of Xi'an Jiatong University, Xian China, Royal Brompton and Harefield NHS Foundation Trust, London, UK and Acutus Medical.

OBJECTIVES: This study sought to validate the accuracy of non-contact electrograms against contact electrograms in the left atrium during sinus rhythm (SR) and atrial fibrillation (AF).

BACKGROUND: Non-contact mapping offers the opportunity to assess global cardiac activation in the chamber of interest. A novel non-contact mapping system, which records intracardiac voltage to derive cellular charge sources (dipole density), allows real-time mapping of AF to guide ablation.

METHODS: Non-contact and contact unipolar electrogram pairs were recorded simultaneously from multiple locations. Morphology correlation and timing difference of reconstructed electrograms obtained from a non-contact catheter were compared with those from contact electrograms obtained from a contact catheter at the same endocardial locations.

RESULTS: A total of 796 electrogram pairs in SR and 969 electrogram pairs in AF were compared from 20 patients with persistent AF. The median morphology correlation and timing difference (ms) in SR was 0.85 (interquartile range [IQR]: 0.71, 0.94) and 6.4 ms (IQR: 2.6, 17.1); in AF was 0.79 (IQR: 0.69, 0.88) and 14.4 ms (IQR: 6.7, 26.2), respectively. The correlation was stronger and the timing difference was less when the radial distance (r) from the non-contact catheter center to the endocardium was < 40 versus > 40 mm; 0.87 (IQR: 0.72, 0.94) versus 0.73 (IQR: 0.56, 0.88) and 5.7 ms (IQR: 2.6, 15.4) versus 15.1 ms (IQR: 4.1, 27.7); $p < 0.01$ when in SR; 0.81 (IQR: 0.69, 0.89) versus 0.67 (IQR: 0.45, 0.82) and 12.3 ms (IQR: 5.9, 21.8) versus 28.3 ms (IQR: 16.2, 36.0); $p < 0.01$ when in AF.

CONCLUSIONS: This novel non-contact dipole density mapping system provides comparable reconstructed atrial electrogram measurements in SR or AF in human left atrium when the anatomical site of interest is < 40 mm from the mapping catheter.

Targeting Nonpulmonary Vein Sources in Persistent Atrial Fibrillation Identified by Noncontact Charge Density Mapping – UNCOVER AF Trial

Circ Arrhythm Electrophysiol. 2019;12:e007233. DOI: 10.1161/CIRCEP.119.007233

Willems, S., Verma, A., Betts, TR, Murray, S., Neuzil, P., Huseyin, I., Steven, D., Sultan, A., Heck, PM, Hall, MC, Tondo, C., Pison, L., Wong, T., Boersma, LV, Meyer, C., Grace, A.

Background: Identification and elimination of nonpulmonary vein targets may improve clinical outcomes in patients with persistent atrial fibrillation (AF). We report on the use of a novel, noncontact imaging and mapping system that uses ultrasound to reconstruct atrial chamber anatomy and measures timing and density of dipolar, ionic activation (i.e., charge density) across the myocardium to guide ablation of atrial arrhythmias.

Methods: The prospective, nonrandomized UNCOVER AF trial (Utilizing Novel Dipole Density Capabilities to Objectively Visualize the Etiology of Rhythms in Atrial Fibrillation) was conducted at 13 centers across Europe and Canada. Patients with persistent AF (>7 days, <1 year) aged 18 to 80 years, scheduled for de novo catheter ablation, were eligible. Before pulmonary vein isolation, AF was mapped and then iteratively remapped to guide each subsequent ablation of charge density–identified targets. AF recurrence was evaluated at 3, 6, 9, and 12 months using continuous 24-hour ECG monitors. The primary effectiveness outcome was freedom from AF >30 seconds at 12 months for a single procedure with a secondary outcome being acute procedural efficacy. The primary safety outcome was freedom from device/procedure-related major adverse events.

Results: Between October 2016 and April 2017, 129 patients were enrolled, and 127 underwent mapping and catheter ablation. Acute procedural efficacy was demonstrated in 125 patients (98%). At 12 months, single procedure freedom from AF on or off antiarrhythmic drugs was 72.5% (95% CI, 63.9%–80.3%). After 1 or 2 procedures, freedom from AF was 93.2% (95% CI, 87.1%–97.0%). A total of 29 (23%) retreatments because of arrhythmia recurrence were performed with average time from index procedure to first retreatment being 7 months. The primary safety outcome was 98% with no device-related major adverse events reported.

Conclusions: This novel ultrasound imaging and charge density mapping system safely guided ablation of nonpulmonary vein targets in persistent AF patients with 73% single procedure and 93% second procedure freedom from AF at 12 months.

High-Resolution Noncontact Charge-density Mapping of Endocardial Activation

JCI Insight. 2019;4(6):e126422. https://doi.org/10.1172/jci.insight.126422.

Andrew Grace, Stephan Willems, Christian Meyer, Atul Verma, Patrick Heck, Min Zhu, Xinwei Shi, Derrick Chou, Lam Dang, Christoph Scharf, Günter Scharf, and Graydon Beatty.

Background: Spatial resolution in cardiac activation maps based on voltage measurement is limited by far-field interference. Precise characterization of electrical sources would resolve this limitation; however, practical charge-based cardiac mapping has not been achieved.

Methods: A prototype algorithm, developed from first principles of electrostatic field theory, derives charge density (CD) as a spatial representation of the true sources of the cardiac field. The algorithm processes multiple, simultaneous, noncontact voltage measurements within the cardiac chamber to inversely derive the global distribution of CD sources across the endocardial surface.

Results: Comparison of CD to an established computer-simulated model of atrial conduction demonstrated feasibility in terms of spatial, temporal, and morphologic metrics. Inverse reconstruction matched simulation with median spatial errors of 1.73 mm and 2.41 mm for CD and voltage, respectively. Median temporal error was less than 0.96 ms and morphologic correlation was greater than 0.90 for both CD and voltage. Activation patterns observed in human atrial flutter reproduced those established through contact maps, with a 4-fold improvement in resolution noted for CD over voltage. Global activation maps (charge density–based) are reported in atrial fibrillation with confirmed reduction of far-field interference. Arrhythmia cycle-length slowing and termination achieved through ablation of critical points demonstrated in the maps indicates both mechanistic and pathophysiological relevance.

Conclusion: Global maps of cardiac activation based on CD enable classification of conduction patterns and localized nonpulmonary vein therapeutic targets in atrial fibrillation. The measurement capabilities of the approach have roles spanning deep phenotyping to therapeutic application.

ACQMAP® CLINICAL OUTCOMES

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Comparison of Procedural Findings between First and Second Retreatment Procedures in Persistent Atrial Fibrillation: The RECOVER AF Study

HRS Abstract 2020 D-PO04-130. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S429.

Timothy Betts, MBChB, MD, Christian Meyer, Andrew A. Grace, MD, PhD, FHRS, Atul Verma, MD, FHRS, Stephen Murray, Simon James, MBBS, Tom Wong, Lucas V.A. Boersma, MD, PhD, Daniel Steven, PhD, Sonia Busch, Petr Neuzil, MD, Carlo de Asmundis, MD, PhD, FHRS, Justin MS Lee, MBChB, MD, CCDS, CEPS-A and Tamas Szili-Torok, MD, PhD. Oxford University Hospitals, Universitätsklinikum Hamburg-Eppendorf, Hamburg, Germany, Royal Papworth Hospital Foundation NHS Trust, Dept of Cardiology, Cambridge, England, United Kingdom, Southlake Regional Health Cent, Toronto, ON, Canada, Freeman Hospital, Newcastle Upon Tyne, United Kingdom, James Cook University Hospital, Middlesbrough, United Kingdom, Royal Brompton and Harefield Hospital, London, United Kingdom, St Antonius Hospital, Nieuwegein, Utrecht, Netherlands, Uni Koeln, Koeln, Germany, Klinikum Coburg, Coburg, Germany, Na Homolce Hospital, Prague, Czech Republic, Vrije Universiteit Brussel, Brussels, Belgium, Cardiology Department, Sheffield, United

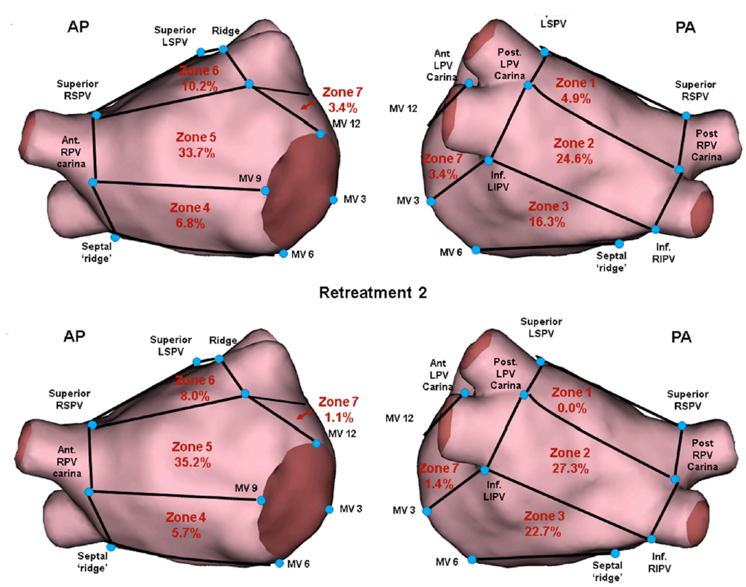
BACKGROUND: Patients with AF often require more than one ablation to maintain SR. The RECOVER AF trial evaluates use of the AcQMap System to guide ablation in patients undergoing 1st or 2nd retreatment.

OBJECTIVE: Evaluate procedural differences between patients at 1st (RT1) or 2nd (RT2) AF retreatment.

METHODS: Between April 2018 and August 2019, 103 patients were enrolled. Reconnected PVs were re-isolated. AF maps (spontaneous or induced) were created and used to guide non-PV ablation. AF could not be induced in 21.8% of RT1 and 12% of RT2 patients. Non-PV targets were classified as Focal (F) >3 firings from same area, Localized Rotation (LR) >270° around a fixed area and Localized Irregular (LI) change of speed and direction through a fixed area. Remapping assessed effectiveness and need for added ablation.

RESULTS: RT2 patients had longer duration of AF (9.9 v 6.5 yr, p=0.008), and smaller left atrial diameter (37.8 v 44.8mm, p<0.01). RT2 patients had fewer reconnected veins (p<0.05). A higher percentage of patients in RT2 had zero reconnections (52.0% v 21.8%, p=0.01) Total ablation time of non-PV targets was similar (29.7 v 27.1 min). Percent of each non-PV target was also similar between RT2 and RT1 (F 14.8% v 9.8%, LR 17.0% v 13.6%, LI 68.2% v 76.5%). Figure 1 Percent of total Non-PV targets located in each zone. Targets were predominately in Zones 2, 3 and 5 for both groups.

CONCLUSION: Target type, location and amount of ablation required are similar for RT1 and RT2, with fewer veins requiring re-isolation by 2nd retreatment. Non-PV electrophysiological substrate remains consistent, unaltered by PV isolation and may therefore be advantageous to target at the earliest opportunity.



	Retreatment 1	Retreatment 1	Retreatment 2	Retreatment 2
Zone 1	13	4.9%	0	0.0%
Zone 2	65	24.6%	24	27.3%
Zone 3	43	16.3%	20	22.7%
Zone 4	18	6.8%	5	5.7%
Zone 5	89	33.7%	31	35.2%
Zone 6	27	10.2%	7	8.0%
Zone 7	9	3.4%	1	1.1%
Total	264		88	

Mapping Post-AF Ablation AT by Using a Novel Charge-Density Mapping System and a Two-Step AT Mapping Workflow

HRS Abstract 2020 D-PO04-163. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S443.

Weidong Lin, Fangzhou Liu, Yumei Xue, Xianzhang Zhan, Hongtao Liao, Ashkan Ehdaie, MD, FHRS, Michael M. Shehata, MD, FHRS, Eugenio Cingolani, MD, Shulin Wu and Xunzhang Wang, MD. Guangdong Cardiovascular Institute, Guangdong Provincial Peoples Hospital, Guangdong Cardiovascular Institute, Guangdong Provincial Peoples Hospital, Guangzhou, China, Cedars Sinai Medical Center, Los Angeles, CA, Cedars Sinai Medical Center, Manhattan Beach, CA, Cedars-Sinai Medical Center, Los Angeles, CA, Cedars Sinai, Los Angeles, CA

Background: Atrial tachycardia (AT) is a very common arrhythmia during and after atrial fibrillation (AF) ablation.

Objective: To evaluate post-AF ablation AT mapping performance using a novel whole chamber non-contact charge density (NCCD) mapping system.

Methods: A total of 29 patients with a previous AF ablation history (mean age of 58 ± 9 years, 12 males, 17 persistent type, LA diameter 47 ± 7 mm) underwent AT ablation using an NCCD mapping system. The mapping strategy consisted of two steps. The first step was to visualize the real-time multi-channel signals and primarily determine which atrium mainly harbored the reentry circuit or origin source. The second step was to map and interpret the mechanism of AT (adenosine was administered during AT with AV relationship of 1:1 or 2:1). The procedural endpoint was AT termination and non-inducibility.

Results: A total of 34 ATs were observed during the procedure, including two ATs with focal mechanism and 32 with reentrant mechanism. There were 13 ATs requiring adenosine injection due to AV relationship of 2:1. The average mapping time was 4.0 ± 1.7 mins/AT, including 0.5 ± 0.2 mins for first step and 3.6 ± 2.3 mins for second step. Although there were four unstable ATs observed (sustained < 2 mins), visible AT propagations still were acquired and interpreted. All patients achieved the procedural endpoint. At a median of 13 (range 7-17) months follow-up, 85.3% of patients remained in SR.

Conclusion: The NCCD mapping system is feasible and effective to rapidly and accurately reveal the mechanism of post-AF ablation AT by using a two-step AT mapping workflow, especially for unstable ATs.

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Spontaneous Cardioversion of Persistent AF following AcQMap-based Ablation

HRS Abstract 2020 D-PO03-S332. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S332.

Darragh Twomey, MBBS, PhD, John Ainsworth, BMedSci, Andy Thornley, MBBS MRCP, Matthew G. D. Bates, MBChB, MRCP, PhD and Simon James, MBBS. James Cook University Hospital, Middlesbrough, United Kingdom

Background: The AcQMap system highlights areas of abnormal conduction during AF. Sites of local rotational, irregular and focal activation are targeted during AcQMap-based AF ablation procedures.

Objective: This study examines the rate of post-procedural spontaneous cardioversion in patients undergoing persistent AF ablation using the AcQMap system in comparison with a control group using standard mapping systems.

Methods: Clinical and procedural data were collected from consecutive patients undergoing persistent AF ablation. Patients receiving PVI only were excluded. Patients who remained in AF at procedure end were included. Short term outcomes following AcQMap-based ablation were compared with procedures using Carto or Precision mapping systems.

Results: 15 patients underwent AcQMap-based ablation and 15 underwent ablation using standard mapping systems. Lesion sets were delivered according to operator preference. Two patients in the AcQMap group had AF induced during the procedure, following recent DCCV from persistent AF.

The groups were well matched; demographic data are presented in table 1.

In the 6 weeks post-procedure, 7/15 patients (47%) reverted to SR spontaneously in the AcQMap group. In comparison, 1/15 patients (3%) in the Carto/Precision group reverted spontaneously over the same period (p=0.035).

AcQMap procedures were significantly longer than those using standard mapping systems (p<0.0001) (table 1). There were no complications.

Conclusion: AcQMap-based ablation is associated with significantly higher rate of post-procedural spontaneous cardioversion from persistent AF than standard ablation and longer procedure duration.

Variable	AcQMap (n=15)	Precision/CARTO (n=15)	p value
Age (yrs)	61.9±6.6	57.6±13.8	NS
Male (%)	15 (100)	14 (93)	NS
Hypertension (%)	7 (47)	6 (40)	NS
LVSD (%)	3 (20)	2 (13)	NS
IHD/CVA/PVD (%)	1 (7)	3(20)	NS
Procedure number	2.3±0.9	1.9±0.8	NS
Procedure duration (mins)	275±34	196±41	p<0.0001
Fluoroscopy duration (mins)	39±14	28±13	P=0.04

Table 1. Patient demographics and procedural data by group

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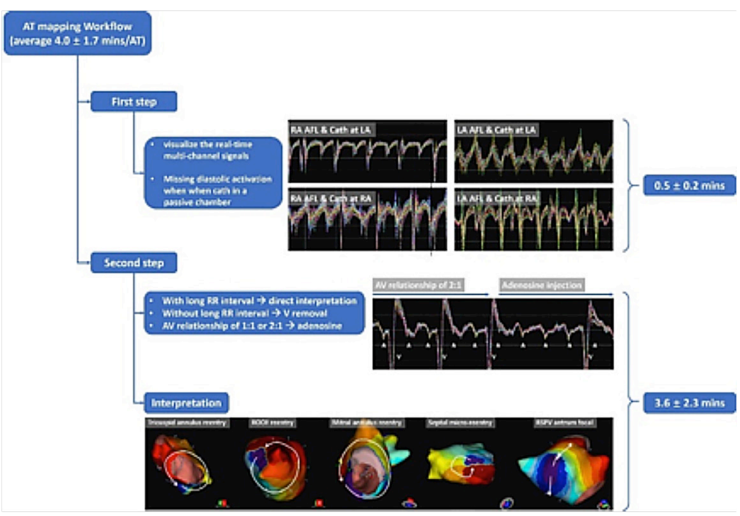
Comparison of Acute Procedural End Points for AcQMap Guided Catheter Ablation of Persistent Atrial Fibrillation vs Conventional Mapping Systems – A Single Centre Experience

HRS Abstract 2020 D-PO02-150. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S252.

Simon James, MBBS, John Ainsworth, B. Med Sci, SCST, Matthew G.D. Bates, MBChB, PhD, Andrew Thornley, MBBS, MRCP, Mohamed Abbas, MBBS MRCP and Darragh Twomey, MBBS, PhD. James Cook University Hospital, Middlesbrough, United Kingdom

Background: AcQMap system uses non-contact sensors to assess continuous activation of the atrium. It can highlight areas of abnormal conduction during AF and allow ablation strategy to be tailored to the individual patient's substrate.

Objective: To compare procedure endpoints in patients undergoing catheter ablation (RFA) of persistent AF using the AcQMap system compared to a those using conventional mapping system.



Methods: Clinical / procedural data were collected for consecutive patients undergoing persistent AF RFA during a 2-year period. System choice for RFA was by operator's preference /not randomised.

Results: 38 patients underwent AcQMap-guided RFA ablation (PVI only =1) and 51 underwent ablation using standard mapping systems (PVI only =18). PVI only cases were excluded from further analysis. Force-sensing RFA catheters were used in all cases. Conventional group were younger (58+/- 9.6 vs 62.7+/- 8 years) and had fewer previous RFA procedures (1.8+/- 0.6 vs 2.3+/- 0.8). Other demographics were well matched (table 1). 11 patients (29.7%) converted to sinus rhythm with RFA alone in AcQMap group compared to 1 (3%) of conventional group (p =0.004). Duration of RF energy was lower in the AcQMap group (23min v 33, p 0.01). AcQMap RFA sites were directed solely by mapping. Conventional group RFA strategy used were Box isolation 55%, Roof line 33% ,LPV-Mitral line 36.%, RPV-Mitral line 12.1%, Cavo-tricuspid isthmus 12%, Fractionation Sites 36.4%.

Conclusion: A patient specific, targeted AcQMap-based substrate approach for persistent AF RFA is associated with significantly higher rate of acute conversion to sinus rhythm, reduced ablation delivery but at the expense of longer procedure and fluoroscopy times.

Variable	Acutus System n=37	Carto/ Precision systems n =33	P Value
Age (yrs)	62.7 (8.4)	58.0 (9.6)	0.027
Male (%)	32 (84.2)	42 (82.4)	ns
CHADS-VASc	1.3 (1.2)	1.1(1.0)	ns
procedure number	2.3 (0.8)	1.6 (0.6)	0.00016
procedure duration (mins)	272 (65)	214 (44)	0.00002
Fluorosopy duration (mins)	34 (14)	22 (9)	0.00003
RFA energy duration	23 (12)	(33 (14)	0.0103
ablation to sinus rhythm (%)	11 (29.7)	1 (3.0)	0.004
redo PVI + substrate ablation (%)	32 (86,5)	29 (87.9)	ns

Table 1. Clinical / Procedural Details ForAcutus and Conventional Mapping AF Cases

First in Man use of the Acutus Medical Contact Mapping Software for the Ablation of Left Atrial Tachycardia

AF Symposium Abstract 2020– AFS2020-41 *Journal of Cardiovascular Electrophysiology*

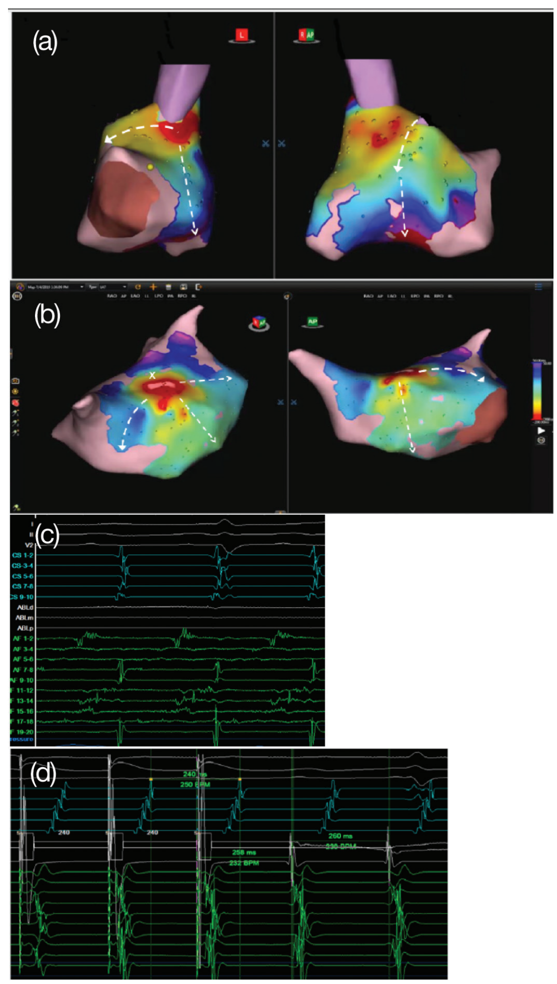
James S, Abbas M, Bates MG, Twomey D, Thornley A. James Cook University Hospital, Middlesbrough, UK.

INTRODUCTION/OBJECTIVES: The Acutus mapping system is a non-contact mapping system used to assess global atrial activation during atrial fibrillation. We describe the first in man use of the Acutus contact mapping software for the ablation of micro-reentrant left atrial tachycardia.

Methods: A 70-year-old man with previous catheter ablation of AV nodal re-entrant tachycardia and typical atrial flutter (AFL) represented with a recurrence of incessant palpitations. His 12 lead ECG was consistent with a recurrence of typical AFL. Ambulatory monitoring confirmed persistent atrial flutter. He underwent catheter ablation.

RESULTS: He was in AFL at baseline with cycle length (CL) of 260 msec. Coronary sinus (CS) activation was proximal to distal. Entrainment from CS 9-10 demonstrated a post pacing interval (PPI) of + 60 msec. Entrainment from CS 1-2 gave a PPI of + 90 msec. Entrainment from the cavo-tricuspid isthmus (CTI) and lateral right atrium (RA) also demonstrated poor PPIs. The best PPI was found in the high RA. Contact mapping of the RA was performed with an Afocus2 20 pole catheter and the Acutus contact mapping system. Activation propagation was high to low along both lateral and septal RA. Less than 50% of the tachycardia CL was recorded in the RA. There was pre-existing block across the CTI. Earliest activation was at the high septal RA (Bachman's bundle). At this site the unipolar electrogram (EGM) did not show a QS EGM and entrainment demonstrated PPI of 50 msec. We concluded the arrhythmia was left atrial in origin. CS pacing at 10 msec and 30 msec < CL showed a PPI disparity of > 30 msec suggestive of a microre-entrant circuit. Transseptal access was obtained and the left atrium (LA) contact mapped demonstrating a microre-entrant tachyarrhythmia arising from the anterior LA adjacent to the right superior pulmonary vein. Fractionated EGMs spanning the entire CL were recorded within a 2cm diameter area. Entrainment from a site of highly fractionated EGM > 120 msec duration demonstrated PPI < 10 msec. Ablation to this site at 35 watts irrigated tip resulted in termination of tachycardia and non-inducibility.

CONCLUSIONS: There were no peri-procedural complications. At 6-months post procedure he is free from all arrhythmia and is taking no anti-arrhythmic drugs.[33]



(a) Acutus contact map of right atrium activation showing passive activation with centrifugal propagation from high septum (Bachman's bundle)

(b) contact map of left atrium showing centrifugal activation propagating from site anterior to the right superior pulmonary vein labeled "x"

(c) intracardiac electrograms recorded at site X spanning the whole cycle length

(d) entertainment from X demonstrating near perfect post pacing interval

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Frequency of Irregular Activation as a Predictor of Recurrence in AcQMap Guided Ablation of Persistent AF

HRS Abstract 2019 PO04-117. Vol. 16, No. 5, May Supplement 2019.

Pope M[1], Kuklik P[2], Betts TR[1]

[1] Department of Cardiology, John Radcliffe Hospital, Oxford University Hospitals NHS Foundation Trust, UK
[2] Department of Cardiology, Electrophysiology, University Medical Center Hamburg-Eppendorf, Germany

Introduction: The use of dipole density mapping (AcQMap, Acutus Medical, CA, USA) facilitates the visualisation of complex conduction patterns during AF, including localised irregular activation (LIA), characterized by directional changes in propagation such as wavefront splitting or pivoting.

Objectives: To develop a method of quantifying LIA in the left atrium and whether it predicts long term outcome from catheter ablation.

Methods: A retrospective cohort of 34 patients who have undergone first time (n=25) or re-do AcQMap guided ablation at a single UK tertiary centre were analysed. LIA was identified using the AcQTrack[1] analysis tool. Areas of low LIA occurrence were removed as outliers to the point of a relative 20% drop in the time LIAs were present throughout whole recording, to ensure adequate specificity and analysis performed using custom designed software. Maps were analysed at baseline, prior to any non-pulmonary vein ablation. LIA was quantified as the total number of detections, percentage time LIA was present at any point in the chamber and the percentage surface area of the chamber covered by LIA pattern occurrence. The mean value from two 5 second recordings was used for analysis.

Results: Over a mean follow up of 12 months, 13 patients (38%) experienced arrhythmia recurrence. This group had a mean number of LIA detections of 154 +/-42 compared to 122 +/-44 in those free from recurrent arrhythmia (mean difference 32, p=0.043). The percentage of time LIA was present during recording was also higher (51% vs. 44%) but was not statistically significant (p=0.104), and there was no difference in the surface area of LIA between groups (6.3 vs. 6.7%). Other variables including baseline rhythm, antiarrhythmic drug use, hypertension, age, BMI, LA size and left ventricular ejection fraction were also analysed with no significant differences seen. In a multivariate model with baseline rhythm, re-do vs. *de-novo* procedure and acute ablation to sinus rhythm, only number of LIA occurrences appeared to significantly predict arrhythmia recurrence (p=0.022).

Conclusion: LIA appears to represent a new marker of AF substrate. As detection methods improve so should specificity and further work will be required to evaluate these regions of complex conduction patterns.

[1]AcQTrack is pending 510(k) approval in the United States.

Use of the AcQMap System to Guide Lesion Placement in Atrial Fibrillation Ablation

HRS Abstract 2019 P002-124. Vol. 16, No. 5, May Supplement 2019.

Darragh Twomey, MBBS, PhD, Mark Edward. Taylor, Sherif Gouda, Andrew R. Thornley, Simon James, Ewen Shepherd, Steve Murray, Moloy Das and Matthew GD. Bates. James Cook University Hospital, Middlesbrough, United Kingdom, Freeman Hospital, Newcastle, United Kingdom

Background: The AcQMap system allows generation of high-density electro-anatomical maps using a spherical catheter composed of 48 ultrasound transducers and 48 biopotential electrodes.

Objective: This multi-centre study documents initial experience of the system to direct lesion delivery in patients undergoing AF ablation.

Methods: Assessment of previous lesions and standard ablation was performed as required. 10-second intervals of AF were then recorded (burst pacing if required). Activation data were collected in AF and separated into 3 types by an automated algorithm — local irregular, local rotational or focal activation. Ablation was performed to transect or isolate these areas. A 21-segment model was used to retrospectively describe the location of targets.

Results: AF ablation was performed in 27 patients (89% male, mean age 61±6 years, 81% persistent). Areas of abnormal activation were found and targeted in 24/27 patients (89%) at a total of 136 sites (*Figure 1*). Sinus rhythm was achieved during AcQMap-based ablation in 5/24 (21%); although all of these cases required AF induction, two had persistent AF. Three further patients with persistent AF spontaneously reverted to sinus rhythm post-procedure, one at 4 hours (induced AF), the other two within 4 weeks. There were no procedural complications. Follow up data was available in 19/27 patients (70%) with a mean duration of 303±222 days; 12/19 (63%) patients were free of AF.

Conclusion: Demonstration of areas of abnormal activation using the AcQMap system is feasible and safe. Targets were most commonly seen in the inferior and anteroseptal aspects of the LA. Early follow up data is encouraging but longer-term assessment is required.

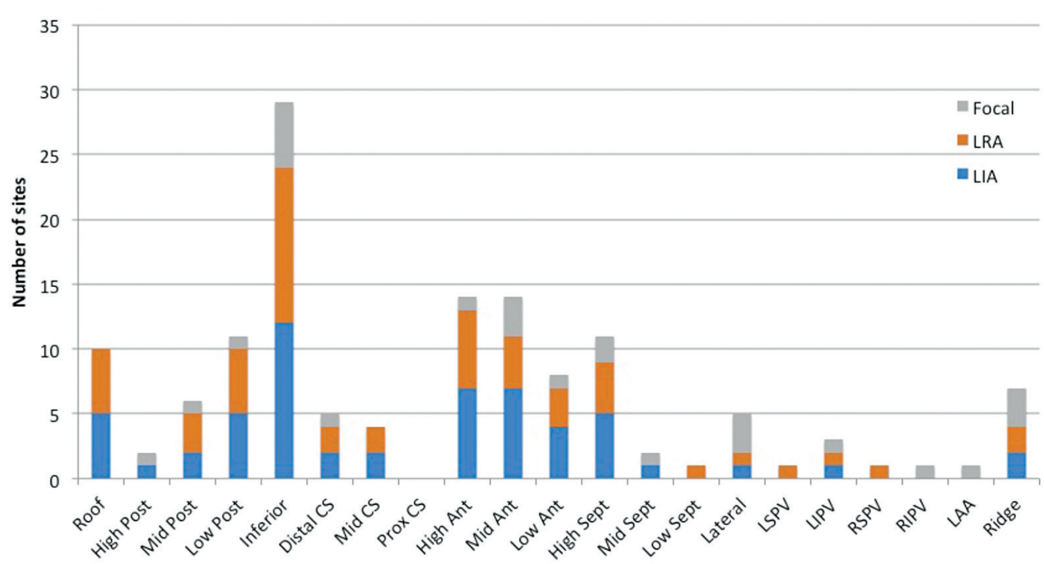


Figure 1. Number of areas of abnormal activation at individual sites.

CASE STUDIES

Dipole Density Mapping of Non-sustained Supraventricular Tachycardia and Characterization of the Atrial Substrate

HRS Abstract 2019 P001-174. Vol. 16, No. 5, May Supplement 2019.

Michael Rochon-Duck, MD, Michael Paikal, Ashkan Ehdaie, MD, FHRS, Michael M.. Shehata, MD, FHRS, Junaid A.B. Zaman, MD, Graydon Beatty, PhD, Xunzhang Wang, MD, and FangZhou Liu. Cedars-Sinai Medical Center, Los Angeles, CA, Stanford University, Palo Alto, CA, Acutus Medical, Carlsbad, CA, Guangzhou, China

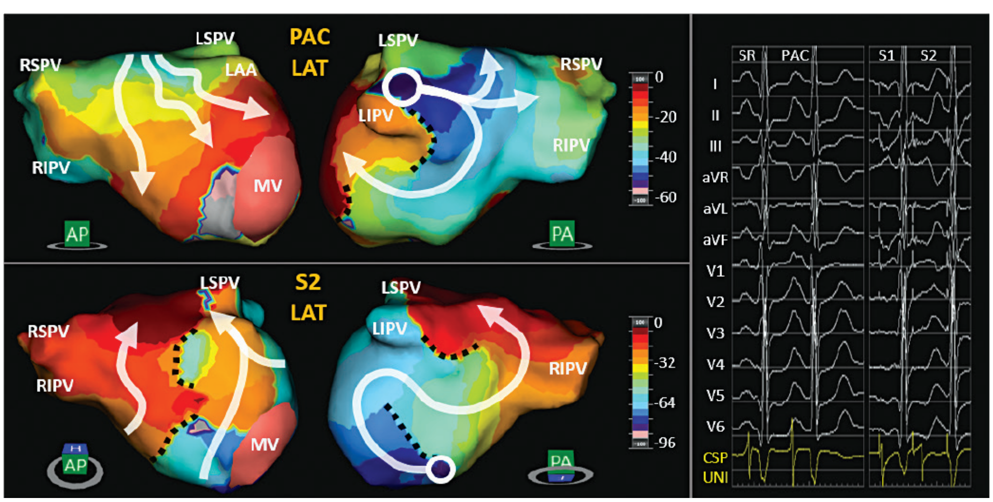
Background: Premature atrial contractions (PACs) and atrial tachycardia (AT) are common arrhythmias, currently mapped using sequential methods.

Objective: To demonstrate use of a noncontact dipole density (NCDD) single beat mapping system for PACs and AT, and to characterize atrial conduction patterns.

Methods: n/a

Results: A 35-year-old female presented with highly symptomatic palpitations, despite metoprolol. An ECG showed initiation of AT with a 260 ms cycle length (CL). At EP study, spontaneous PACs and nonsustained AT with 1:1 AV conduction and 375 ms CL were seen. PAC morphology was positive in lead I, inferior leads, and V1. Sustained AT was induced with isoproterenol and atrial pacing. A 48-element NCDD mapping catheter (Acutus Medical, Carlsbad, CA) was introduced into the left atrium (LA) via transeptal puncture. Global activation was displayed as a dynamic, three-dimensional DD map during sinus rhythm (SR), AT, and LA programmed stimulation. LA conduction time was ~60ms during SR and AT but lengthened to 95ms with a short-coupled S2 (240 ms). During AT, focal activation originated from the left superior pulmonary vein (LSPV). Complex, rhythm-specific conduction and functional block patterns were observed. AT terminated during encircling RF ablation of the LSPV (irrigated, contact-force catheter) and was then noninducible. After five months she remains free of symptoms off medication.

Conclusion: NCDD mapping rapidly localized the site of LA PACs initiating AT and characterized complex, rhythm-specific conduction patterns.



LAT maps of pre-ablation PAC and S2, with S1/S2/S3 protocol = 580/240/240 ms. LA conduction time was 65, 60, 63, and 95 ms for SR, PAC, S1, and S2, respectively, during Isoproterenol infusion.

Atrial Fibrillation in an Isolated Box Caught on Cam

HRS Abstract 2019 P003-036. Vol. 16, No. 5, May Supplement 2019.

Author Block: *Ben JM. Hermans, Tammo Delhaas, MD,PhD and Laurent Pison, MD,PhD. Department of Biomedical Engineering, Maastricht University, Maastricht, Netherlands, Cardiology Dept., Maastricht University Medical Centre, Maastricht, Netherlands*

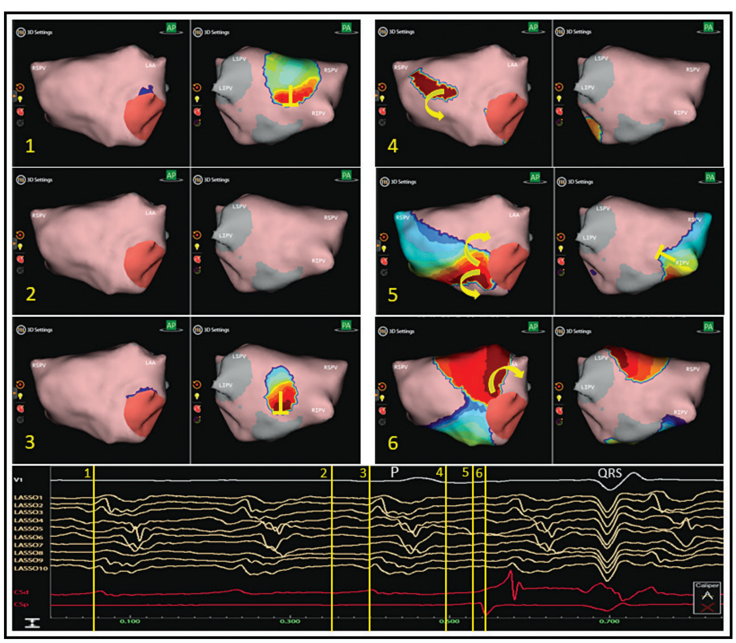
Background: Conventional mapping systems are unable to map complex activations that comprise atrial fibrillation (AF). The AcQMapTM system is a non-contact mapping system that enables global mapping of complex atrial arrhythmias. A novel catheter uses ultrasound transducers to reconstruct anatomy and electrodes to record intracardiac unipolar signals from which a dipole density map is reconstructed.

Objective: Investigating whether the AcQMapTM system is able to visualize AF within an isolated box during sinus rhythm (SR) which happened during the procedure by chance.

Methods: N/A

Results: A 73-year-old man with persistent atrial fibrillation (AF) was referred for a re-do AF ablation. The patient presented in atrial tachycardia. Intensive biatrial mapping and ablation was done. Spontaneous conversion to SR was achieved between ablations. Ablation lines from prior procedures were checked in SR. While checking for block using the AcQMap system, conduction within the posterior box lesion of the LA exhibited AF in contrast with the SR conduction present in the LA. A lasso contact catheter was placed inside the isolated box to record and demonstrate local AF (figure). The first and third snapshot of the propagation movie show depolarization fronts on the posterior wall of the LA as well as on the lasso catheter. Between these two time points, 'electrical silence' can be seen on both the Lasso catheter and the AcQMap® propagation map. Snapshots 4, 5 and 6 show SR activation fronts in the remaining LA.

Conclusion: Although there are still artifacts visible during 'electrical silence', the AcQMap® system can help visualize AF within an isolated portion of tissue while the rest of the atria are in SR.



ATRIAL FIBRILLATION MECHANISMS

ACUTUS™
MEDICAL

ACQMAP CLINICAL COMPENDIUM

ACUTUS MEDICAL

Impact of Adenosine on Wavefront Propagation in Persistent Atrial Fibrillation

HRS Abstract 2020 D-PO04-152. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S438.

Michael T.B. Pope, BM, CCDS, Pawel Kuklik, PhD, Andre Briosa e Gala, MD, John Paisey, MD, Michael Mahmoudi, PhD and Timothy Betts, MBChB, MD. Oxford University Hospitals NHS Foundation Trust, Oxford, United Kingdom, University Medical Center Hamburg-Eppend, Hamburg, Germany, Oxford University Hospitals NHS Foundation Trust, Oxford, United Kingdom, University Hospital Southampton, Southampton, United Kingdom, Oxford University Hospitals, Oxford, United Kingdom

Background: The effect of adenosine on electrophysiological phenomena during AF is poorly understood.

Objective: To analyse the impact of adenosine on mechanisms of AF propagation.

Methods: The study included 22 patients undergoing ablation for persistent AF using the AcQMap non-contact mapping system. Recordings of AF propagation were made before and after administration of adenosine at one or more of 3 time points during the procedure: pre-pulmonary vein isolation (PVI), post PVI, or at the end of the case. QRS-T signals were subtracted and data was analysed using custom designed software to quantify localised rotational activation (LRA), localised irregular activation (LIA) and focal firings (FF) identified by the in-built AcQTrack[1] tool. Virtual dipoles were exported and phase mapping applied to calculate the global cycle length (AFCL) and identify phase singularities (PS). Low frequency of activation patterns were removed to increase specificity using cut offs resulting in a relative 5, 10, 20 and 30% drop in the time each pattern was present over the recording. Patterns were quantified for the number of occurrences, percentage time present, and the surface area affected.

Results: Analysis included 35 paired 5 second segments. Adenosine shortened global mean AFCL from 182±14 to 165±16 (difference 17ms, 95% CI 11-22, p<0.0005). With no cut off adenosine resulted in an increase in LRA occurrences from 16±8 to 24±10 (8, 4-12; p<0.0005) with a 14% (7-20; p<0.0005) increase in the time LRA was present but only a 7% (3-11; p0.001) increase in surface area affected. These findings were consistent across all cut offs but with minimal effect on LRA surface area (<2%) at higher cut offs with 67% of LRA regions in the same location as LRA at baseline. PS numbers increased from 30±8 to 37±9 (7, 3-10, p<0.002) and duration increased by 90ms (13-167, p=0.023). There was a small increase in LIA occurrences only at lower cut offs and no change in the surface area affected. There was no difference in the frequency of FF. At median follow up of 9 months, 91% were free of AF recurrence.

Conclusion: Adenosine shortens global AFCL and promotes rotational activation, which occurred at a higher frequency and duration but covering a similar atrial surface area. This may imply a possible mechanistic role of rotational activation patterns in AF maintenance.

[1]AcQTrack is pending 510(k) approval in the United States.

Electrophysiological Characteristics of Atrial Fibrillation Phenotypes Before and After Pulmonary Vein Isolation using Charge Density Mapping

HRS Abstract 2020 D-PO06-100. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S611.

Fang-zhou Liu, MD, PhD, Ashkan Ehdaie, MD, FHRS, Michael Shehata, MD, FHRS, Eugenio Cingolani, MD, Yumei Xue, MD, PhD, Shu-lin Wu and Xunzhang Wang, MD. Guangdong Province Peoples Hospital, China, Cedars Sinai Medical Center, Los Angeles, CA, Cedars-Sinai Medical Center, Los Angeles, CA, Guangdong Provincial Hospital, Guangdong, China, Cedars Sinai, Los Angeles, CA

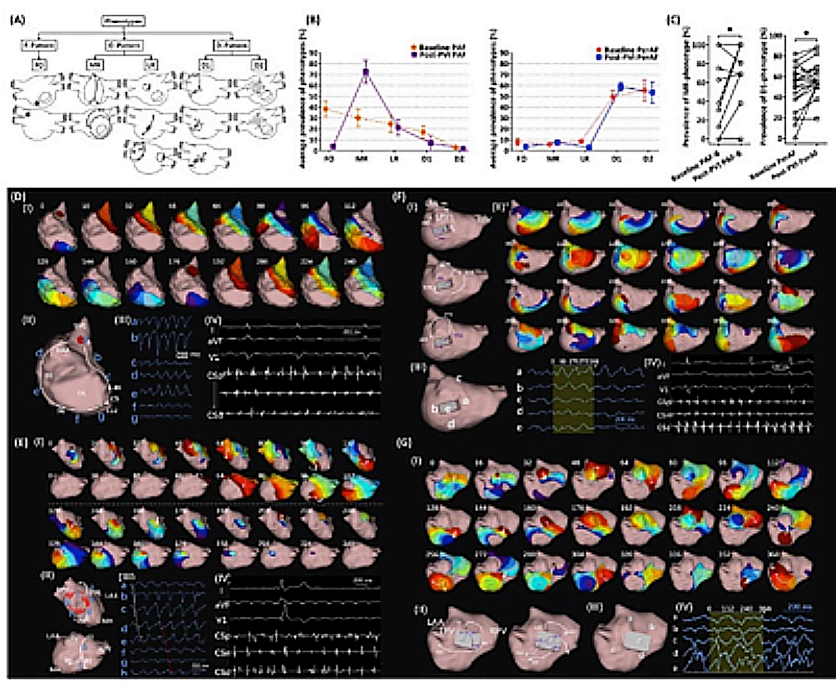
Background: Clinical understanding of AF remains unclear.

Objective: Identify phenotypes that maintain paroxysmal and persistent AF (PAF and PerAF) and characterize their differences before and after pulmonary vein isolation (PVI).

Methods: Forty patients with AF (PAF=21, PerAF=19) were studied. Baseline and post-PVI AF maps were generated (16-s duration) and phenotypes were identified using non-contact charge-density (NCCD) mapping (Acutus Medical). All the phenotypes were visually identified, verified by intracardiac signals and categorized into three primary conduction-patterns: focal (FO); organized reentrant pattern (O); and disorganized rotational pattern (D).

Results: A total of 142 phenotypes (FO-Pattern=35, O-Pattern=44, D-Pattern=63) were identified from all 40 baseline AF maps, with O-Patterns and D-Patterns mechanistically respectively divided into two sub-types. O-Patterns were divided into macro-reentrant (MR = 17) and local-reentrant (LR = 27). D-Patterns were divided into constrained disorganized reentry (D1 = 37) and disorganized reactivation (D2 = 26). The average regional number and prevalence of D-Patterns was higher in PerAF, while O-Patterns and F-Patterns were higher in PAF. In addition to elimination of PV-related phenotypes, the overall prevalence of MR in PAF and D1 in PerAF were increased after PVI.

Conclusion: EP phenotypes differed between PAF and PerAF as well as before and after PVI. As expected, PAF was more organized than PerAF. However, PVI also led to a higher prevalence of marco-reentry in PAF and constrained disorganized reentry in PerAF. This may provide new insight for improving ablation strategies in PAF and PerAF.



ACUTUS MEDICAL

Spatiotemporal Couplings Characterized by Non-Contact Charge-Density Mapping in Paroxysmal and Persistent Atrial Fibrillation

HRS Abstract 2020 D-PO03-217. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S373.

Fang-zhou Liu, MD, PhD, Ashkan Ehdaie, MD, FHRS, Michael M. Shehata, MD, FHRS, Eugenio Cingolani, MD, Yumei Xue, MD, PhD, Shu-lin Wu and Xunzhang Wang, MD. Guangdong Province Peoples Hospital, China, Cedars-Sinai Medical Center, Los Angeles, CA, Guangdong Provincial Hospital, Guangdong, China, Cedars Sinai, Los Angeles, CA

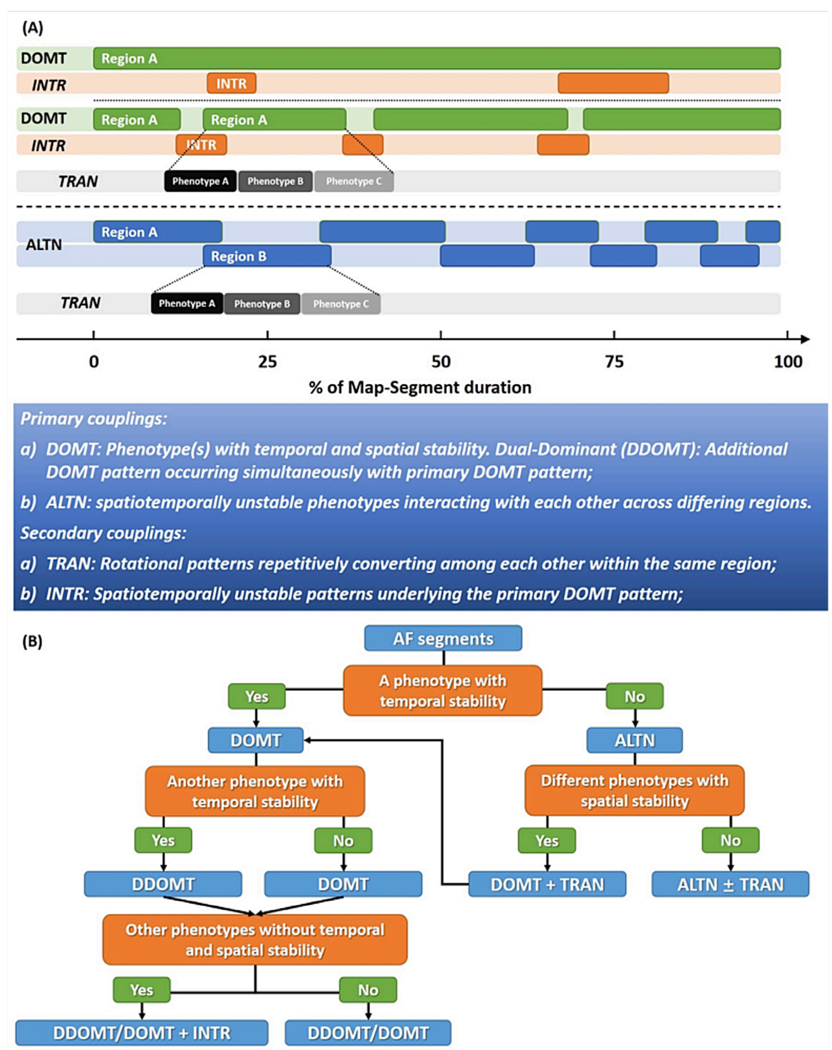
Background: Non-contact charge-density (NCCD) mapping has been used to characterize AF phenotypes.

Objective: Characterize spatiotemporal coupling of AF phenotypes in paroxysmal and persistent AF (PAF and PerAF) using NCCD.

Methods: Twenty-one PAF and 19 PerAF patients were studied. AF maps were generated (16-s segment) and phenotypes were identified using NCCD mapping (Acutus Medical). Three primary conduction-pattern phenotypes were identified: focal (F); organized (O); and disorganized (D). Prevalence of phenotypes were calculated as a percentage over each segment. Temporal and spatial stability was respectively defined as a given phenotype prevalence ≥ 75% over the segment and different phenotype prevalence ≥ 75% within the same region.

Results: Four spatiotemporal couplings were identified, with two primary types: dominant (DOMT) and alternating (ALTN); and two secondary types: transitional (TRAN) and intermittent (INTR). Forty primary and 48 secondary couplings were identified. ALTN is common in PAF (0.52 ± 0.51/segment), while DOMT in PerAF (0.68 ± 0.48/segment). Secondary couplings are more prevalent in PerAF than PAF (1.95 ± 0.85 vs. 0.52 ± 0.60/segment). TRAN is the main secondary coupling in PAF (0.29± 0.46/segment) and PerAF (1.16 ± 0.50 /segment). Full spatial and temporal stability both were observed in 10 PAF segments. However, while spatial stability was observed in 13 PerAF segments and temporal stability was only observed in five PerAF segments.

Conclusion: Maintenance of AF is mediated by different combinations of couplings. Spatiotemporal stability is governed.



ACUTUS MEDICAL

Spatiotemporal Stability of Conduction Patterns in Persistent Atrial Fibrillation: Insights from the UNCOVER AF Trial

HRS Abstract 2020 D-PO04-195. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S457.

Douglas Darden, MD, Paras Parikh, PhD, CEPS, Stephan Willems, MD, Atul Verma, MD, FHRS, Timothy Betts, MBChB, MD, Steve Murray, MD, Stephen Murray, Stephan Murray, Petr Neuzil, MD, Hüseyin Ince, MD, Daniel Steven, PhD, Arian Sultan, MD, Patrick M. Heck, BM, Mark Hall, MBBS, Claudio Tondo, Laurent Pison, MD, PhD, Tom Wong, Lucas V.A. Boersma, MD, PhD, Christian Meyer, MD, Christian Meyer, Andrew A. Grace, MD, PhD, FHRS, Gregory K. Feld, MD, FHRS and Jonathan C. Hsu, MD, FHRS. UC San Diego, Acutus Medical, Carlsbad, CA, Asklepios Hospital St Georg Hamburg, Hamburg, Germany, Southlake Regional Health Cent, Toronto, ON, Canada, Oxford University Hospitals, Oxford, United Kingdom, James Cook Univ Hospital, Middlesbrough, United Kingdom, Freeman Hospital, United Kingdom, Na Homolce Hospital, Prague, Czech Republic, University Hospital Rostock and Vivantes Klinikum, Uni Koeln, Koeln, Germany, University Heart Center Cologne, Cologne, Germany, Papworth Hospital, Cambridge, United Kingdom, Manchester Heart Centre, Warrington, United Kingdom, Centro Cardiologico Monzino, Milano, Italy, Maastricht UMC+, Maastricht, Netherlands, Royal Brompton and Harefield Hospital, London, United Kingdom, St Antonius Hospital, Nieuwegein, Utrecht, Netherlands, Braunav, Austria, Universitätsklinikum Hamburg-Eppendorf, Hamburg, Germany, Royal Papworth Hospital Foundation NHS Trust, Dept of Cardiology, Cambridge, England, United Kingdom, Univ of California San Diego, La Jolla, CA, University of California, SanDiego, Cardiac Electrophysiology Section, La Jolla, CA

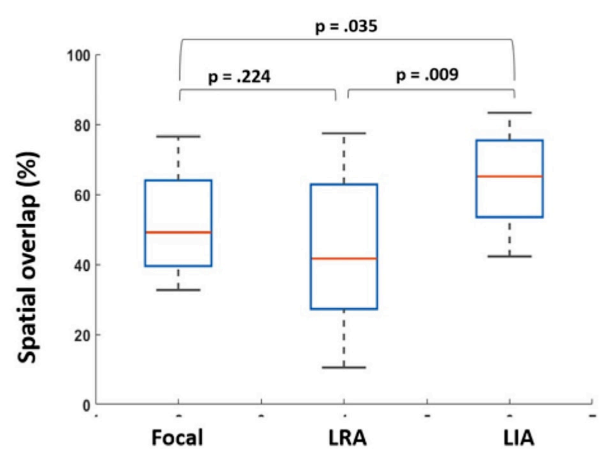
Background: Non-contact charge density (NCCD) mapping (AcQMap, Acutus Medical) has identified three distinct non-pulmonary vein (PV) conduction patterns in patients with persistent AF (PersAF): focal (F); localized rotational activation (LRA); and localized irregular activation (LIA). Targeting these areas for ablation, in addition to PV isolation (PVI) has been shown to decrease arrhythmic burden, however characterization of these patterns is incomplete.

Objective: Assess spatiotemporal stability of NCCD-identified conduction patterns in persAF.

Methods: NCCD maps were generated from pre-PVI recordings in 20 patients enrolled in the UNCOVER AF trial who underwent de novo catheter ablation for persAF. Patterns were assessed in 7 distinct recording epochs (1, 2, 5, 10, 15, 20, and 30 s). The top 30% of detected patterns for each epoch were compared to the previous epoch. Median spatial percentage overlap throughout the 30 s windows (n = 20) was calculated for each pattern and compared across epochs.

Results: A total of 140 recordings were analyzed. Over the entire 30 s, the percentage spatial overlap (median, IQR) was: F (0.49, 0.38 – 0.66); LRA (0.65, 0.51 – 0.75); LIA (0.42, 0.23 – 0.65). F and LRA patterns were similar (p = 0.224), while LIA had statistically significantly higher percentage spatial overlap than F (p = 0.035) and LRA patterns (p = 0.009). Furthermore, LIA stabilized at 15 s, while F and LRA failed to stabilize over 30 s (Figure).

Conclusions: In PersAF, NCCD-identified LIAs displayed the highest spatial consistency and stabilization compared to F and LRA patterns, as expected given the intermittence of F and LRA. LIA may be a more reliable metric for identifying non-PV ablation targets in PersAF.



Comparison of percentage spatial overlap of detected patterns across all recorded epochs (n=20)

Spatial Stability of Complex Propagation Patterns in Atrial Fibrillation

AF Symposium Abstract 2020 - AFS2020-21 *Journal of Cardiovascular Electrophysiology*

Michael Pope, BM MRCP, P Kuklik, PhD, Andre Briosa e Gala, MD, Michael Mahmoudi, PhD, John Paisey, MD, Timothy Betts, MD, John Radcliffe Hospital Department of Cardiology, Level 2, Headley Way, Headington, Oxford, OX3 9DU

Introduction/Objectives: Global non-contact charge density mapping identifies complex patterns of wavefront propagation during atrial fibrillation (AF) including localised rotational activation (LRA), localised irregular activation (LIA) and focal firing (FF). However, it is not clear to what extent these patterns are stable over time and reflect the underlying structural atrial substrate. We sought to evaluate the stability of LRA, LIA and FF patterns between 2 separate AF recordings with the aim of identifying how they represent the stable arrhythmia substrate.

Methods: Patients undergoing first time catheter ablation procedures using the AcQMap system were studied. Two separate 30s recordings of left atrial propagation were analysed. LIA, LRA, and FF were quantified for every occurrence at each vertex of the chamber anatomy and displayed on the surface anatomy. Frequency is depicted as a colour scale. Spatial stability was assessed by correlating the frequency of propagation patterns at each vertex of the chamber anatomy over the 2 recordings. Stability of regions with the most repetitive patterns were compared using Cohen's kappa statistic.

Results: 11 patients were analysed in total (age 62±8, 8 male, BMI 30±6, CHA2DS2Vasc 1±0.9, ejection fraction 57±7%, left atrial diameter 47±7mm, paroxysmal AF 1, persistent AF 10). LIA demonstrated the greatest stability with average R2 value of 0.76±0.14. Average R2 values for LRA and FF were 0.45±0.16 and 0.47±0.12 respectively. Multiple low frequency focal firings were seen widely distributed across the atrial surface (see figure 1). For FF occurring at a frequency ≥10 over the 30s, average R2 value was 0.65±0.14 compared with 0.24±0.10 where FF occurred with a frequency < 5 over the 30 seconds. Cohen kappa statistic was 0.70 for LIA and 0.45for LRA.

Conclusions: LIA demonstrates high spatiotemporal stability and may best reflect disrupted propagation caused by the underlying atrial substrate and tissue architecture. Regions of high frequency FF are temporally stable and may represent important targets for ablation.[16]

SUBSTRATE CHARACTERIZATION

ACUTUS™ MEDICAL

Regions of Highly Irregular Activation Patterns during Atrial Fibrillation Correlate with Reduced Local Conduction Velocity in Sinus Rhythm

HRS Abstract 2020 D-PO04-147. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S436.

Michael T.B. Pope, BM, CCDS, Pawel Kuklik, PhD, Nathan Angel, Paras Parikh, PhD, CEPS, John Paisey, MD, Michael Mahmoudi, PhD and Timothy Betts, MBChB, MD. Oxford University Hospitals NHS Foundation Trust, Oxford, United Kingdom, University Medical Center Hamburg-Eppend, Hamburg, Germany, Acutus Medical, Carlsbad, CA, University Hospital Southampton, Southampton, United Kingdom, Oxford University Hospitals, Oxford, United Kingdom

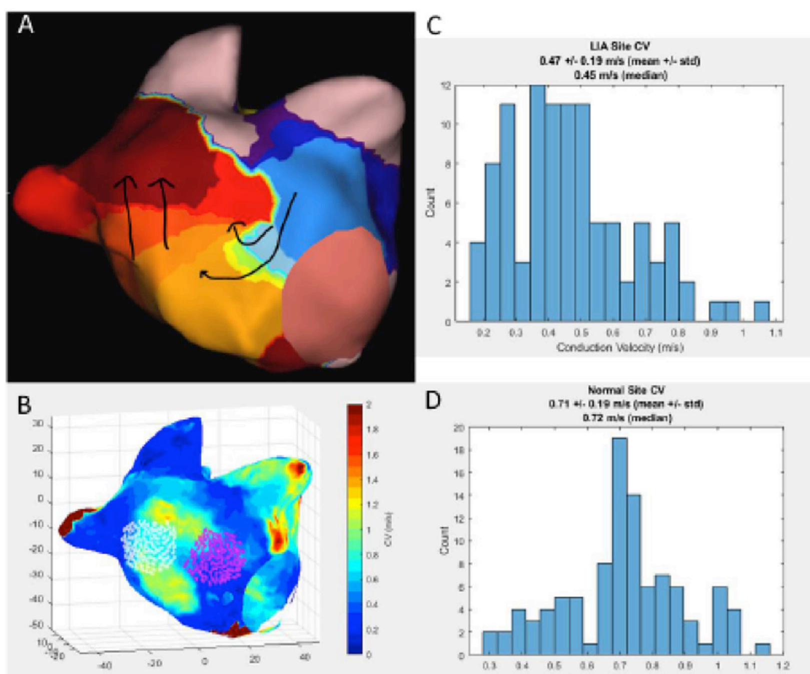
Introduction: AcQMap charge density mapping reveals regions with localised irregular activation (LIA) patterns. The properties of these regions in sinus rhythm is poorly understood.

Objective: To compare conduction velocity (CV) during pacing between regions of repetitive LIA and more uniform, passive activation during AF.

Methods: Patients undergoing non-contact AcQMap guided ablation were studied. 30 second recordings of AF propagation and recordings during pacing at 800ms cycle length from either the coronary sinus or left atrial appendage were obtained with external cardioversion to restore sinus rhythm or burst pacing to induce AF used as necessary. LIA regions were identified using the in-built AcQTrack[1] tool. Additional regions equidistant from the pacing site that displayed more uniform 'passive' activation were chosen for comparison. Following demarcation of these zones, pacing maps were created and exported for analysis. Local CV was estimated using a method of polynomial surface fitting and the median value for each region used for comparison. Differences in CV were compared using a paired t-test.

Results: A total of 12 patients were included (age 62, male = 7, BMI 31.6, ejection fraction 44%, left atrial diameter 44mm). In the 12 patients, 14 regions of LIA and paired regions with uniform propagation were identified. Median CV in LIA regions was 0.67±0.28 compared to 1.34±0.90 in regions with uniform CV with a difference of 0.67, 95% confidence interval 0.18 – 1.16, p=0.12.

Conclusion: Regions with repetitive LIA during AF demonstrate relative slow CV during pacing compared to adjacent zones with uniform propagation suggestive of a possible role of these zones in AF maintenance.



A. Popagation history maps showing a region of irregular pivoting propagation during AF adjacent to a zone of uniform propagation. **B.** Conduction velocity map with comparison regions highlighted and distribution of conduction velocities in these zones shown in **C** (LIA zone) and **D** (uniform zone).

[1]AcQTrack is pending 510(k) approval in the United States.

Quantification and Analysis of Atrial Fibrosis using Late Gadolinium-Cardiac MRI (LGE-CMRI) in Long Standing Persistent AF Ablation

HRS Abstract 2020 D-MP03-01 *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S644.

Anitha G Sathish Kumar, BS, CEPS, CCDS, Shouvik Haldar, MBBS, MD, Pawel Kuklik, PhD, Alice Snell, MBBS, Vennela Boyalla, MBBS, MRCP, Nabeela Karim, MBBS, MRCP, Rui Shi, MD, PhD, Paras Parik, PhD, Jennifer Keegan, PhD and Tom Wong, MBBS, MD. Cambridge University Hospitals, Royal Brompton Hospital, Royal Brompton & Harefield Hospital, United Kingdom, Acutus Medical Inc, Royal Brompton Hospital, Royal Brompton Hospital, London, United Kingdom, Royal Brompton & Harefield NHS Trust, LONDON, United Kingdom, Royal Brompton and Harefield Hospital, London, United Kingdom.

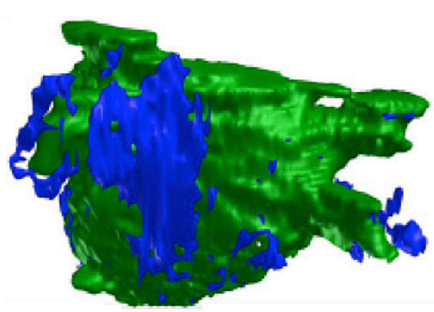
Background: Atrial fibrosis is the hallmark of structural remodeling in AF and is the substrate of AF maintenance. We present our results on analysis of atrial fibrosis using LGE_CMRI in LSPAF from CASA-AF Pilot study.

Objective: To quantify surface atrial fibrosis from baseline pre-ablation LGE_CMRI scans and study the relationship with ablation outcomes.

Methods: 39 patients who underwent LSPAF ablation with pre-ablation LGE-CMRI during AF. Open software, Slicer3D was used for manual LA=segmentation and automated scar delineation. The K-means clustering algorithm was used to cluster pixels outside the endocardial surface of the 3D-geometry to delineate scar. The delineated surface scar (blue) and LA endocardial 3D-geometry (green) is exported to a proprietary software to calculate the burden (blue/green%). Any signal 5mm from the endocardial surface was excluded. The duration since AF, success at 6m&1y to its relationship to atrial fibrosis burden.

Results: 61.5% (24/30) of the LGE-CMRI data were analyzable. Median surface atrial fibrosis was 12.5 +/- 5.98% (Max 28.40%). There was a weak positive correlation between duration of AF to the atrial fibrosis burden (p = 0.36, P = 0.09, Spearman's). The 1-year recurrence rate of AF/AT post ablation was significantly higher in patients with more than 10% atrial fibrosis burden compared to less than 10%, 8/16 (50%) vs 3/8 (37.5%), P= less than 0.001 respectively.

Conclusion: Our data shows that the burden of atrial fibrosis increases as duration of AF progresses. High pre-ablation fibrosis burden (more than 10%) is associated with higher recurrence rate in LSPAF. LGE-CMRI could be useful as a non-invasive diagnostic tool for patient selection.



Post RFA - Follow up	ATRIAL FIBROSIS & POST ABLATION RECURRENCE	
	Recurrence in <10% Atrial fibrosis burden %(n) *Tot N = 8*	*Recurrence in >10% Atrial fibrosis burden %(n)* *Tot N=16*
6 months	12.5% (1)	43.7% (7)
1 year	37.5% (3)	50.0% (8)

Image shows manually segmented left atrial 3D model (Posterior view) in green and delineated surface scar in blue.
Table shows the extent of atrial fibrosis to number of AT/AF recurrence at 6 months and 1 year.

ACUTUS™ MEDICAL

Right Atrial Substrate Mapping in Persistent AF

HRS Abstract 2020 D-AB01-05. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S2.

Anitha G. Sathish Kumar, BS, CEPS, CCDS, Junaid A.B Zaman, MD, PhD, CCDS, Omar Hatem Mohamed Amin Riad, MBChB, MSci, Richard Chambers, MS, Derrick Chou, PhD, Nabeela Karim, MBBS, Vennela Boyalla, MBBS, MRCP, Rui Shi, MD, PhD, Alice Snell, MBBS, Shouvik Haldar, MBBS, MD, Karen McCarthy, PhD, S. Yen Ho, PhD and Tom Wong, MBBS, MD. Cambridge University Hospitals, Royal Brompton Hospital, London, United Kingdom, Royal Brompton Hospital, London, United Kingdom, Acutus Medical, San Diego, CA, Acutus Medical, Carlsbad, CA, Royal Bromton Hospital, London, United Kingdom, Royal Brompton & Harefield Foundation NHS Trust, London, United Kingdom, Royal Brompton & Harefield NHS Trust, London, United Kingdom, Royal Brompton Hospital, London, United Kingdom, Royal Brompton & Harefield, London, United Kingdom, Royal Brompton Hospital, National Heart & Lung Institute, London, United Kingdom, Royal Brompton and Harefield Hospital, London, United Kingdom

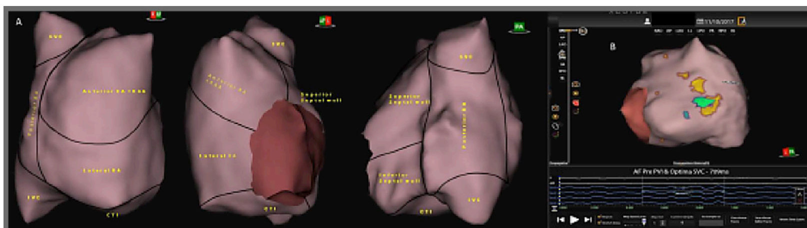
Background: Data is limited regarding right atrial activation patterns (RA) prior to left atrial ablation during persistent AF (PerAF).

Objective: To study the frequency and distribution of RA activation patterns during PerAF.

Methods: We studied pre-ablation RA charge density (Acutus Medical, Carlsbad, CA) maps of PerAF patients. 5s of AF activations between TQ intervals (excluding T waves) were studied and converted to propagation history maps after noise exclusion. The RA was divided into 9 anatomical zones (Fig A). The RA activation map was slowed to 1/50th speed and analysed for different activation patterns, their frequencies & distributions.

Results: 16 patients were studied (25% long standing PerAF). A total of 118 TQ segments were studied with a median 560ms (317 – 2176ms). A mean of 165.6 +/- 12.7 activation patterns occurred in mean of 4.94 +/- 0.20 secs of PerAF giving a total of 2554 activation patterns in 80s of AF. Of these 21.1% (N=541, pink) were focal centrifugal activity, 3.1% (N=79, green) were complete rotational activity (≥270-degreee rotation), 75.6% were local irregular activity (N=1934, yellow) (Fig C). Al patients had repeated occurrence of more than 2 types of activation patterns at posterior wall & septum junction (FigB). 48.7% of activation patterns were in the posterior wall and septum junction and 26.1% at the anterior RA/RAA.

Conclusion: The junction between RA posterior wall & septum is a new substrate with heterogeneous conduction in PerAF. RAA also has significant activations occurring during AF, perhaps secondary to pectinate muscle fibres. The benefit of ablating these areas is currently under investigation.



C

Activation patterns of Interest	Posterior wall –Septum Junction	Anterior RA/RAA
Focal Centrifugal Activity (FCA)	38.5%	31.4% (Including crista region)
Localized Rotational Activity (LRA)	45.7%	36.7% (significant occurrence at Septum – RAA junction)
Localized Irregular Activity (LIA) (Slow conduction & micro-reentry were commonest LIAs observed)	54.5% (slow conduction)	23.0% (slow conduction)
	54.5% (micro re-entry)	24.3% (micro re-entry) (significant occurrence at Septum – RAA junction)

Initial Observations on the Relationship between Left Atrial Substrate and Atrial Activation during AcQMap Guided AF Ablation

Heart Rhythm Congress 2019. *European Journal of Arrhythmia & Electrophysiology*, Vol. 5, Suppl 1.

Tom Nelson, Nicholas Kelland, Peter Metherall, Michael Sharkey, Justin Lee

Background: Ablation of persistent AF remains a significant challenge. Charge density mapping is a novel tool for use in atrial fibrillation (AF) ablation. The AcQMap system (Acutus Medical) maps the chamber via a non-contact static hybrid charge density / ultrasound catheter. Its algorithm identifies regions of interest (ROIs) according to three subtypes: local irregular activity (LIA), local rotational activity (LRA) and focal activation (FA).

Methods: Consecutive patients attending for ablation for persistent AF had both bipolar voltage maps (EnSite Precision, Abbott) and charge density maps recorded at baseline in AF. Voltage maps were recorded using multipolar catheters with thresholds of <0.1mV for dense scar and >0.5mV for healthy tissue. AcQMaps were parameterised according to operator experience. Images were co-registered and visual comparison of the AcQMap ROIs and voltage maps performed by two independent observers (TN / JL). Discrepancies were discussed and agreed by consensus.

Results: Paired maps for eight male patients (mean age 63, range 58-70 years) were analysed. Four had previously undergone pulmonary vein (PV) isolation, one had undergone three prior procedures with PV, LA roof and mitral isthmus ablation and the remainder were de novo procedures. In all cases PVs were (re)isolated and then AcQMap guided ablation performed.

The mean atrial voltage across all subjects was 0.59mV (SD 0.89) with an average of 66% of points below 0.5mV (range 38% to 86%) indicating a significant scar burden in our cohort. Areas of low voltage were observed in 70 of 96 atrial segments, with the PV exhibiting the lowest voltage (19 of 32 veins had areas with voltage <0.1mV).

6 +/- 1 AcQMap ROIs were identified for each individual for a total of 46 ROIs (20 LIA, 14 LRA and 12 FA). 17 ROIs were posterior, 15 anterior and 14 were within PVs. We did not identify a predilection for ROIs in any anatomic location. When compared with voltage maps, most ROIs (n=29, 63%) occurred in either low- or intermediate- voltage regions, with a further 6 (13%) adjacent to low voltage areas. 11 (24%) were in preserved voltage areas. FA tended to occur in low voltage areas, whereas LIA / LRA occur most commonly where voltage >0.1mV.

Currently mean follow up duration is 155 days and five of eight patients are free from AF. Two have had cardioversion for AF within a one month blanking period post ablation, while one had a cardioversion for right atrial flutter.

Discussion: Most ROIs were situated in or adjacent to low (<0.5mV) or very low (<0.1mV) voltage areas, and this may reflect the diseased substrate of our PeAF population. Given this extensive scarring, an effective ablation strategy was challenging to determine based on voltage data alone. Approximately 1/3rd of ROIs were seen within PVs and a further 1/3rd in the posterior LA. These ROIs would have been treated by our usual strategy of PVI and posterior box, but in 1/3rd of patients the ROIs were anterior and would have been missed with standard approaches. Further analysis of the relationship between AF activation (LIA, LRA, focal) and LA substrate is planned.

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First in Man use of Acutus SuperMap Algorithm for Stepwise Ablation of Persistent Atrial Fibrillation

AF Symposium Abstract 2020 – AFS2020-42 *Journal of Cardiovascular Electrophysiology*

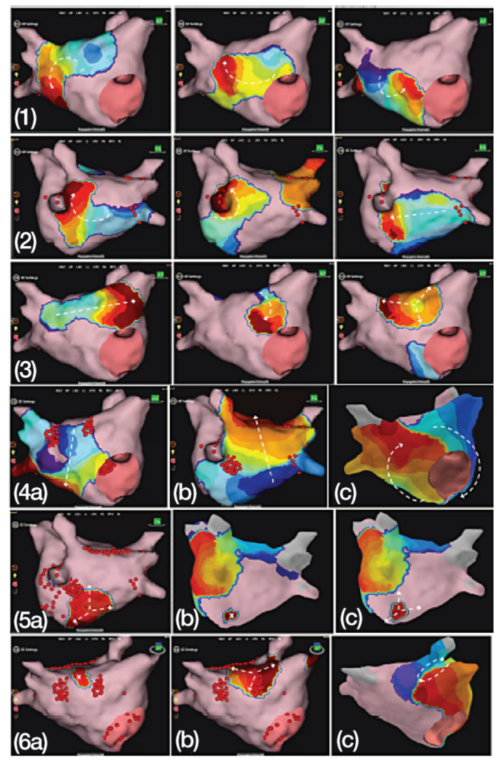
James S, Abbas M, Bates MG, Thornley A, Twomey D. James Cook University Hospital, Middlesbrough, UK.

INTRODUCTION/OBJECTIVES: AcQMap (Acutus medical) uses non-contact sensors to enable a continuous global view of activation within a chamber. The new SuperMap algorithm provides rapid collection of high-density non-contact data for rhythms that exhibit a degree of organisation. We describe first experience of using this technology to guide a stepwise approach to persistent atrial fibrillation (AF) ablation.

METHODS: A 77-year-old male CHADSVASc-4 with drug refractory symptomatic persistent AF underwent pulmonary vein isolation (PVI) in 2012. Persistent AF recurred in 2016. He failed to maintain sinus rhythm (SR) despite multiple cardioversions and amiodarone. He was referred back for redo-ablation.

RESULTS: Ablation (RFA) to discrete sites re-isolated right superior (RSPV), right inferior and left inferior pulmonary veins (LIPV). Left superior vein was isolated at baseline. AcQMap showed abnormal activation at LA roof, posterior to LIPV, anterior to RSPV (fig 1,2,3). RFA to these sites converted to typical RA flutter. RFA to the cavotricuspid isthmus restored SR but AF was re-induced while pacing to confirm isthmus block. AcQMap showed intermittent cycles of roof dependent flutter (4). RFA of roof line organized activation completely to clockwise perimitral flutter (4). RFA from LIPV to mitral valve annulus (MVA) including cs lesions caused an abrupt cs activation change and 20 msec cycle length (CL) increase. Entrainment from cs, anterior MVA, roof and posterior LA all demonstrated poor post pacing interval (PPI). Posterior MVA had best PPI of CL + 30. SuperMap demonstrated focal /microreentrant site inferior LA (5). RFA here resulted in further change in CL and CS activation. Entrainment was poor throughout LA. Best PPI was +40 from base of LAA. AcQMap suggested focal activation spreading from a site area anterior to roof line. However higher resolution SuperMap highlighted micro-reentry between LAA and roof line (6). There were low amplitude polyphasic catheter electrograms spanning the whole CL at this site. RFA to this site terminated tachycardia and restored SR.

CONCLUSIONS: It was no longer possible to re-induce AF. The patient has remained in sinus rhythm at > 6 months. SuperMap / AcQMap allows for patient specific stepwise ablation strategy for persistent AF ablation.[32]



Examples of AcQMap of left atrial activation patterns during stepwise ablation for persistent AF:

1. Frequent activation passing anterior to RSPV in multiple directions
2. Activation in multiple directions posterior to LIPV
3. Activation passing through anterior to roof in multiple directions and spreading centrifugally from focal site
4. Depolarisation passing over roof and around right pulmonary veins (a, b) and SuperMap of clockwise perimitral flutter (c)
5. AcQMap (a) and SuperMap (b, c) showing focal activation from inferior LA
6. Apparent focal/centrifugal activation anterior to roof line (a, b) demonstrated to be due to reentry between base of LAA and roof line with SuperMap (c)

Validation of SuperMap® Multi-Position Non-Contact Mapping in Complex Atrial Tachycardias

HRS Abstract 2020 D-PO05-162. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S533.

Rui Shi, MD, PhD, Anitha Sathish Kumar, Vias Markides, MBBS, MD, David Gareth Jones, MBBS, MD, CEPS, Wajid Hussain, MD, Shouvik Haldar, MBBS, MD, Mark Norman, Elyar Ghafoori, MS, Nathan Angel, Richard Chambers, MS, Derrick Chou, PhD, Graydon Beatty, PhD, Junaid A.B Zaman, MD, PhD, CCDS and Tom Wong. Royal Brompton & Harefield NHS Trust, London, United Kingdom, Royal Brompton & Harefield NHS FT, London, United Kingdom, Harefield Hospital, Harefield, United Kingdom, Royal Brompton & Harefield, London, Milton Keynes, United Kingdom, Royal Brompton & Harefield NHS Trust, Amersham Buckingham, United Kingdom, Acutus Medical, Carlsbad, CA, Acutus Medical, San Diego, CA, Royal Brompton Hospital, London, United Kingdom, Royal Brompton and Harefield Hospital, London, United Kingdom

Background: Mapping complex atrial tachycardias (AT) can be challenging due to low voltage atrial electrograms (EGM) in areas of abnormal conduction. Multi-position non-contact (MPNC) mapping uses a stable reference to time-align non-contact (NC) data acquired with a 48-electrode catheter (AcQMap) during AT, using a charge-density inverse solution to reconstruct EGMs across the chamber.

Objective: To evaluate reconstructed NC vs. measured contact EGMs during AT.

Methods: MPNC maps (N=15) were acquired in 10 patients. During MPNC data acquisition, contacting electrodes (N=7740) were considered gold standard contact EGMs and used for comparison. Cross-correlation and time lag were calculated between measured contact EGMs and the nearest reconstructed NC EGMs from the MPNC map. The peak to peak (P2P) unipolar voltage was computed for both contact and NC EGMs. A paired t-test was used to assess similarity of P2P voltages.

Results: MPNC maps were acquired over 131 ± 30 s. The cross-correlation and time lag between resulting reconstructed NC EGMs and measured contact EGMs was 0.91 [0.81,0.97] and 1.6 [0.00,4.48] ms (median [25%,75%]) respectively. The median P2P voltage for contact (3.23±1.86 mV) and NC (3.23±2.01 mV) were not significantly different (p=0.95) for each map. Figure 1 shows an example of contact and NC EGM trace comparisons.

Conclusion: MPNCM is a novel mapping method that quickly acquires data to map complex AT. NC EGMs accurately reconstruct morphology, timing and amplitude of unipolar contact EGMs, including low voltage areas that are often critical sites for maintaining AT.

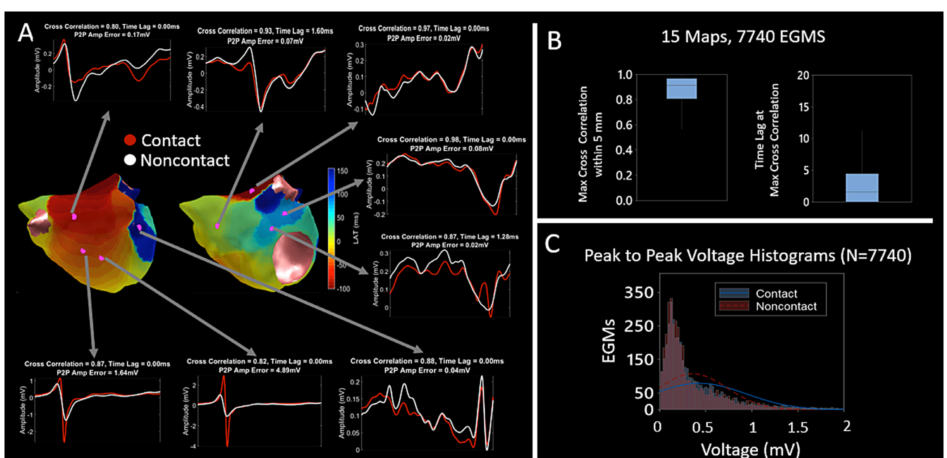


Figure 1) Noncontact Supermap EGMs, compared with contact EGMs. A) A representative example of contact and noncontact EGMs collected from different locations of a patient with complex atrial tachycardia. Both sites with high amplitude RS morphology sites and low amplitude fractionated sites in conducting isthmus are accurately reproduced with non contact mapping using Supermap. B) Maximum cross correlation and time lag at maximum cross correlation, within 5 mm search area, between contact and noncontact EGMs. C) The comparison between contact and noncontact unipolar peak to peak voltage distribution.

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Simultaneous Mapping of Multiple Regular Rhythms with SuperMap® Multi-Position Non-Contact Mapping

HRS Abstract 2020 D-PO05-166. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S535.

Rui Shi, MD, PhD, Anitha Sathish Kumar, Vias Markides, MBBS, MD, David Gareth Jones, MBBS, MD, CEPS, Wajid Hussain, MD, Shouvik Haldar, MBBS, MD, Mark Norman, Min Zhu, Pratik Shah, Xinwei Shi, Tom Wong and Junaid A.B Zaman, MD, PhD, CCDS. Royal Brompton & Harefield NHS Trust, United Kingdom, Royal Brompton & Harefield NHS FT, London, United Kingdom, Harefield Hospital, Harefield, United Kingdom, Royal Brompton & Harefield NHS Trust, London, United Kingdom, Royal Brompton & Harefield, London, Milton Keynes, United Kingdom, Royal Brompton & Harefield NHS Trust, Amersham Buckingham, United Kingdom, Acutus Medical, CA, Acutus Medical, San Diego, CA, Royal Brompton and Harefield Hospital, London, United Kingdom, Royal Brompton Hospital, London, United Kingdom

Background: Mapping regular rhythms with varying cycle lengths (CLs) can be challenging and time consuming when each rhythm must be independently mapped. SuperMap, a novel multi-position non-contact (MPNC) mapping method, automatically differentiates and groups unique rhythms according to unipolar beat morphology and creates a high-resolution activation map for each group.

Objective: Evaluate SuperMap accuracy in grouping unique rhythms *in silico* and *in vivo*.

Methods: Focal activations were simulated from 15 locations on a left atrial (LA) model. Twelve electrode locations were used to simulate unipolar CS EGMs. Simulations were repeated varying the number of CS electrodes (4, 8 and 12) and active focal sites (2, 3 and 4). For each of these 9 combinations, the active focal sites were randomized 25 times to produce varying CS beat morphologies (N=225) to test grouping accuracy. In a preclinical study, a continuous recording with mixed CS distal pacing (CSd), proximal pacing (CSp) and sinus (SR) was acquired. *In vivo* clinical recordings (N=7) were collected during CSd and CSp pacing in 3 patients.

The grouping accuracy was evaluated by F-score, $F = 2TP / (2TP + FP + FN)$.

Results: The mean grouping accuracy *in silico* was F=0.977. Preclinical *in vivo* mean grouping accuracy for SR, CSd, and CSp is F=0.949. Clinical *in vivo* mean accuracy is F=0.983.

Conclusion: SuperMap demonstrates the ability to differentiate and group unique rhythms with high accuracy based on differences in CS beat morphology.

Evaluation of Amplitude Maps Produced by SuperMap® Multi-Position Non-Contact Mapping in Stable Arrhythmias

HRS Abstract 2020 D-PO05-173. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S539.

Rui Shi, MD, PhD, Anitha Sathish Kumar, Vias Markides, MBBS, MD, David Gareth Jones, MBBS, MD, CEPS, Wajid Hussain, MD, Shouvik Haldar, MBBS, MD, Mark Norman, Pratik Shah, Richard Chambers, MS, Derrick Chou, PhD, Xinwei Shi, Graydon Beatty, PhD, Junaid A.B Zaman, MD, PhD, CCDS and Tom Wong. Royal Brompton & Harefield NHS Trust, United Kingdom, Royal Brompton & Harefield NHS FT, London, United Kingdom, Harefield Hospital, Harefield, United Kingdom, Royal Brompton & Harefield NHS Trust, London, United Kingdom, Royal Brompton & Harefield, London, Milton Keynes, United Kingdom, Acutus Medical, CA, Acutus Medical, San Diego, CA, Acutus Medical, Carlsbad, CA, Royal Brompton Hospital, London, United Kingdom, Royal Brompton and Harefield Hospital, London, United Kingdom

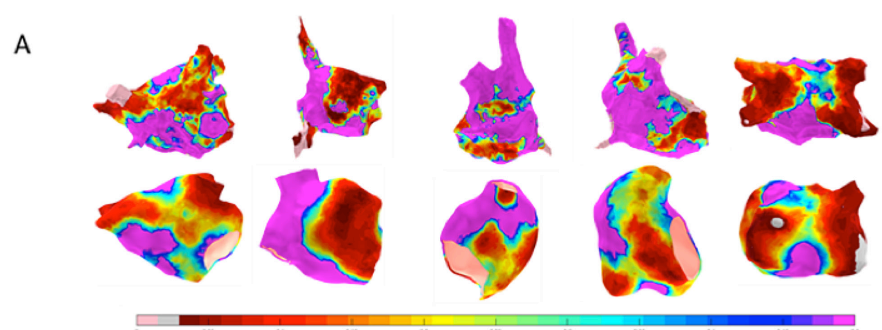
Background: Bipolar voltage amplitude of contact (C) electrograms (EGMs) is commonly used to assess abnormal tissue in stable arrhythmias. SuperMap, a novel multi-position, non-contact (NC) mapping method (Acutus Medical) time aligns data from multiple catheter positions to a stable reference to reconstruct unipolar charge density EGMs that allow rapid creation of high-resolution, full-chamber maps of the arrhythmia.

Objective: Compare the correspondence between SuperMap amplitude maps (SAMs) and bipolar voltage amplitude maps (BAMs) generated by contact EGMs.

Methods: Bipolar voltage C measurements were collected using the HDGrid (Abbott Labs) system in 5 patients and interpolated (≤ 1 cm) to create BAMs. NC measurements (> 5 mm from the surface) were collected using SuperMap. A SAM was created by applying a Laplacian operator on charge density EGMs and estimating the peak to peak amplitude. Low amplitude points (LAP) (<= 0.5 mV) were extracted from SAMs and BAMs. KL divergence (KLD) was calculated between SAM and BAM LAP distributions. KLD is used to estimate the similarity between two distributions. To establish a reference measurement of similarity, KLD was also calculated for LAPs close in proximity (LAPc, < 1 mm) after registering SAM and BAM geometries. For LAPc, similarity between distributions was tested using a KS test.

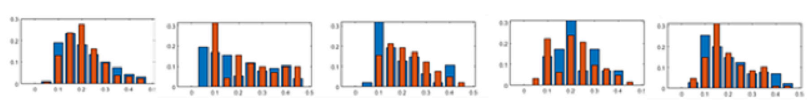
Results: KLD for LAPs was between [0.004,0.09] ([min,max]), which was in the same range ([0.005,0.10]) as KLD for LAPc. A KS test showed that the distribution of LAPc BAMs and SAMs was not significantly different (α= .01), implying that the distribution of LAP BAMs and SAMs are similar.

Conclusions: SuperMap can produce amplitude maps comparable to C BAMs.



KL divergence	0.014	0.059	0.09	0.02	0.004

B



p- value	0.53	0.031	0.035	0.42	0.202
KL divergence	0.005	0.10	0.07	0.057	0.014

A. For 5 patients, BAM (first row) and SAM (second row). KL divergence is the similarity between two distributions of low amplitude points (LAP). **B.** histogram for LAPs that are closer than 1mm (LAPc) (blue: BAM, orange: SAM). Table shows the p-value for KS test performed on LAPc and corresponding KL divergence.

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Identifying Critical Isthmuses during Reentrant Atrial Tachycardia using SuperMap® Multi-Position Non-Contact Charge Density Mapping

HRS Abstract 2020 D-PO05-172. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S538.

Rui Shi, MD, PhD, Anitha Sathish Kumar, Vias Markides, MBBS, MD, David Gareth Jones, MBBS, MD, CEPS, Wajid Hussain, MD, Shouvik Haldar, MBBS, MD, Mark Norman, Nathan Angel, Xinwei Shi, Junaid A.B Zaman, MD, PhD, CCDS and Tom Wong. Royal Brompton & Harefield NHS Trust, United Kingdom, Royal Brompton & Harefield NHS FT, London, United Kingdom, Harefield Hospital, Harefield, United Kingdom, Royal Brompton & Harefield NHS Trust, London, United Kingdom, Royal Brompton & Harefield, London, Milton Keynes, United Kingdom, Acutus Medical, CA, Acutus Medical, San Diego, CA, Royal Brompton Hospital, London, United Kingdom, Royal Brompton and Harefield Hospital, London, United Kingdom

Background: Reentrant atrial tachycardias (AT) can be challenging to map due to low amplitude atrial electrograms in areas of abnormal conduction. Low amplitude regions often contain isthmuses critical to maintenance of the arrhythmia. SuperMap, a multi-position, non-contact (MPNC) mapping method (AcQMap, Acutus Medical), time-aligns data from multiple catheter positions to a stable reference to quickly create high-resolution, full-chamber maps that can be used to identify these critical isthmuses.

Objective: Evaluate SuperMap's ability to determine the critical isthmus in reentrant AT.

Methods: In a retrospective analysis, SuperMap was used to create propagation maps (n=9) of reentrant AT in 8 patients, from which active area (AA) maps and streamline (SL) plots were made. AA maps indicate the percent of atrial tissue that is active (depolarizing) during the AT cycle length. Valleys in AA maps are often concurrent with isthmus conduction. SL plots show the flow of conduction by tracking atrial depolarization throughout the cardiac cycle. Sites of isthmus conduction were identified within the valley of the AA plot with SL exiting the region with outward conduction. These sites were compared to the ablation site that resulted in SR.

Results: SuperMap data was acquired in 132 ± 45 s. All patients were ablated to SR. The AA maps and SL plots identified the site of rhythm termination in 8/9 cases.

Conclusion: AA maps with SL plots derived from SuperMaps can be used to identify isthmus conduction during reentrant AT.

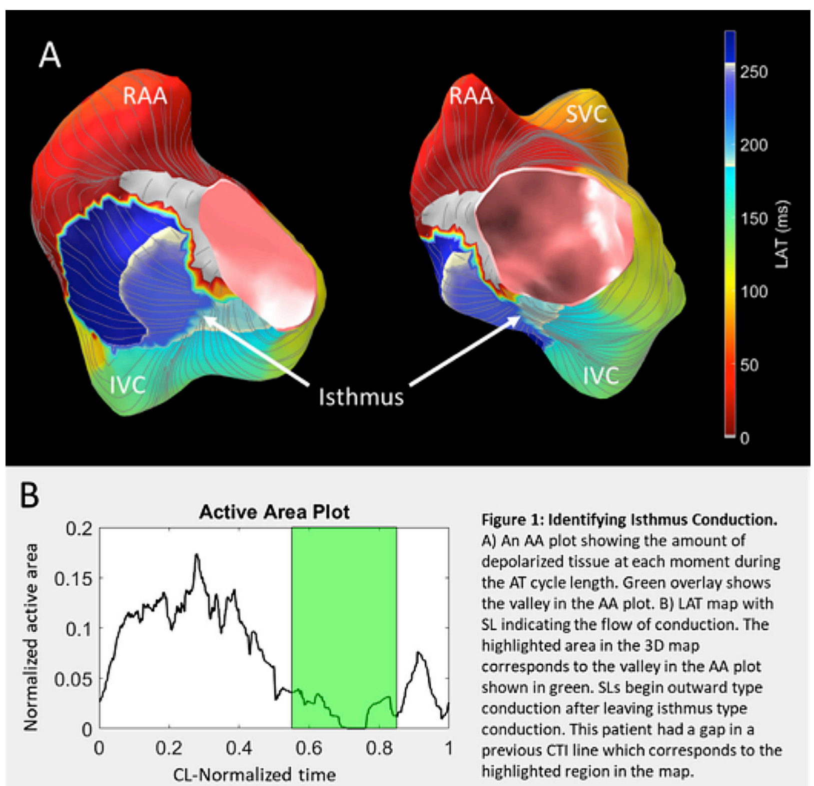

Figure 1: Identifying Isthmus Conduction. A) An AA plot showing the amount of depolarized tissue at each moment during the AT cycle length. Green overlay shows the valley in the AA plot. B) LAT map with SL indicating the flow of conduction. The highlighted area in the 3D map corresponds to the valley in the AA plot shown in green. SLs begin outward type conduction after leaving isthmus type conduction. This patient had a gap in a previous CTI line which corresponds to the highlighted region in the map.

"SuperMap" – Utility of High-Density Non-Contact System for Synchronous Mapping of Atrial Pacing

HRS Abstract 2020 D-PO05-164. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S534.

Michael T.B. Pope, BM, CCDS and Timothy Betts, MBChB, MD. Oxford University Hospitals NHS Foundation Trust, Birmingham, United Kingdom

Introduction: "SuperMap" is a new algorithm for the mapping of organized atrial arrhythmias using the AcQMap non-contact mapping system.

Objectives: To undertake mapping during atrial pacing at varying cycle lengths from a static site in order to test the utility of the system.

Methods: Maps were created following cardioversion in 3 patients undergoing catheter ablation for AF. Pacing was performed from the proximal coronary sinus at output twice threshold using a repeating protocol of a 3 beat drive train followed by a single extra-stimulus at 10ms longer than the effective refractory period. Outcomes assessed were the time taken for map creation and display, the accuracy of beat detection/grouping at the 2 pacing cycle lengths and the number of atrial points included for each beat detection.

Results: Recordings were taken for 5 minutes (m) 1 second (s), 4 m 33 s and 2 m 58 s respectively. Automated post-processing took 1 m 8 s, 39 s and 25 s resulting in total times from the start of mapping to viewing a map of 6 m 9 s, 5 m 12 s and 3 m 22 s.

In all patients, the 2 cycle lengths were accurately discriminated. Automated beat detection identified 2 groups for patient one (occupying 73% and 25% of signals), 4 groups in patient 2 (23%, 20%, 18% and 16%) and 4 groups in patient 3 (30%, 24%, 11% and 8%). The additional beat groups were a result of ectopy and sinus beats following occasional non-capture. Following manual adjustment of the beat detection window grouping was improved to 56%, 20% and 3% in patient 2 and 60%, 10%, 10% and 7% in patient 3. See table for full results.

Conclusion: The "SuperMap" algorithm is quick and accurately able to discriminate rhythms based on cycle length alone. Minor manual adjustment of the beat detection window may be required for optimization.

Patient	Patient 1		Patient 2				Patient 3			
Total mapping time	6m 9s		5m 12s				3m 22s			
Number of automatic beat groups	2		4				4			
Beat groups identified and %	800ms (73%)	400ms (25%)	800ms (23%)	800ms with t-wave (20%)	380ms (18%)	800ms (16%)	800ms (30%)	800ms (24%)	Loss of capture (11%)	340ms (8%)
Number of EGM mapping points included	11,147	4,051	2231	1558	2295	1582	2249	2125	656	190
Manual adjustment beat groups identified and %	N/A		800ms (56%)		380ms (20%	Ectopy (3%)	800ms (60%)	Loss of capture (10%)	Ectopy (10%)	340ms (7%)
Number of EGM mapping points included	N/A		5432		2266	213	5196	363	894	712

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In Vivo Accuracy and Efficiency of a Novel Non-Contact Method (SuperMap) for Full-Chamber, Ultra-High-Density Maps of Stable Arrhythmias

HRS Abstract 2020 D-PO05-169. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S536.

Junaid A.B. Zaman, MD, PhD, CCDS, Min Zhu, Derrick Chou, Pratik Shah, Janice Barstad, Richard Chambers, Xinwei Shi, Rui Shi, Anitha Satish Kumar, Graydon Beatty and Tom Wong. Royal Brompton Hospital, Acutus Medical, Carlsbad, CA

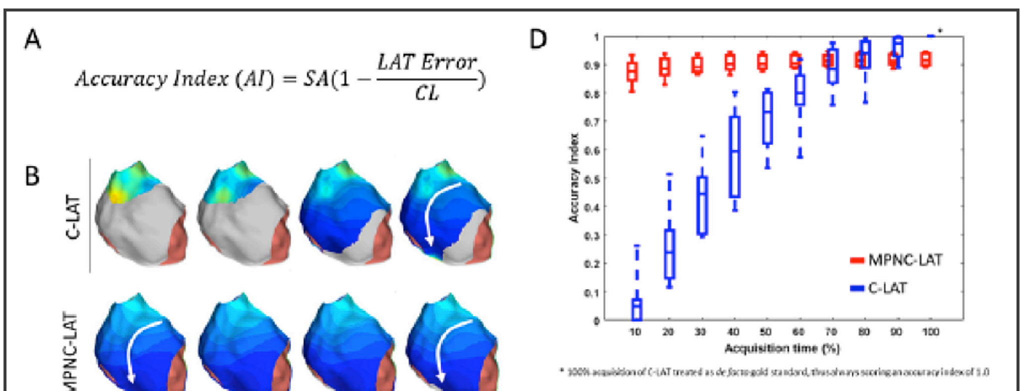
Background: Contact maps measure local activation times (LATs) across multiple cycles of stable arrhythmias relative to fiducial points. Higher resolution maps generated from higher density point collection require extended procedure time.

Objective: To demonstrate the accuracy and efficiency of a novel mapping method (SuperMap, Acutus Medical, Carlsbad, CA USA) that aligns multiple non-contact (NC) catheter positions (CPs) to a stable timing reference in repetitive rhythms.

Methods: NC and contact (C) recordings were collected at multiple CPs in 10 patients who terminated via ablation of persistent AF to atrial tachycardia or flutter. All cycles were time aligned. A charge density inverse solution used accumulated NC CPs to create a series of multi-position NC (SuperMap) LAT maps - each map used a larger number of CPs. Complementary sets of Contact LAT maps were also created (figure B, C). SuperMap LAT (SM-LAT) and contact LAT (C-LAT) maps were compared using accuracy index, shown in figure A. LAT error was calculated as mean absolute error against the final C-LAT map.

Results: SM-LAT maps required 53% less time than C-LAT to achieve AI of 0.9. SM-LAT maps have 7.4x greater density of points as compared to C-LAT in the same acquisition time (mean 125.9 ± 24.2 s). (Figure D, E)

Conclusion: In clinical use, the SuperMap multi-position non-contact mapping method quickly produces ultra-high-density maps of repetitive rhythms with high accuracy.



Method	Mean # of pts	Mean Point Density (pts/cm²)
C-LAT	486	2.9
MPNC- LAT	3652	21.6

A Equation for accuracy index computation – SA: surface area, CL: cycle length, LAT error: mean absolute time error vs. final C-LAT map ***B-C*** *In vivo* C-LAT and MPNC-LAT maps of RA-AFL & LA-AFL, respectively, at 4 progressive time points. ***D*** *In vivo* MPNC-LAT and C-LAT accuracy index vs. % acquisition time across 5 AT/AFLs. ***E*** Table of average number of points and area point density across 14 in vivo AT/AFLs.

Multi-position, Non-contact Method for Full-chamber, Ultra-high-density Maps *in silico* & *in vivo* Stable Arrhythmias

HRS Abstract 2019 P006-007. Vol. 16, No. 5, May Supplement 2019.

Junaid Zaman1, Min Zhu[2], Pratik Shah[2], Nathan Angel[2], Xinwei Shi[2], Derrick Chou[2], Graydon Beatty[2], Xunzhang Wang[3], Christoph Scharf[4], Munmohan Virdee[1], Andrew Grace[1]

[1]Papworth; [2]Acutus Medical; [3]Cedars-Sinai; [4]Klinik Im Park, Zurich

Background: Stable arrhythmia contact maps measure local activation times (LATs) across multiple cycles relative to a fiducial time reference. Higher resolution can be achieved with a higher density of points collected across the entire chamber at the expense of extended procedure time.

Objective: Demonstrate feasibility and efficiency of a novel mapping method that aligns multiple non-contact (NC) catheter positions (CPs) in stable arrhythmias.

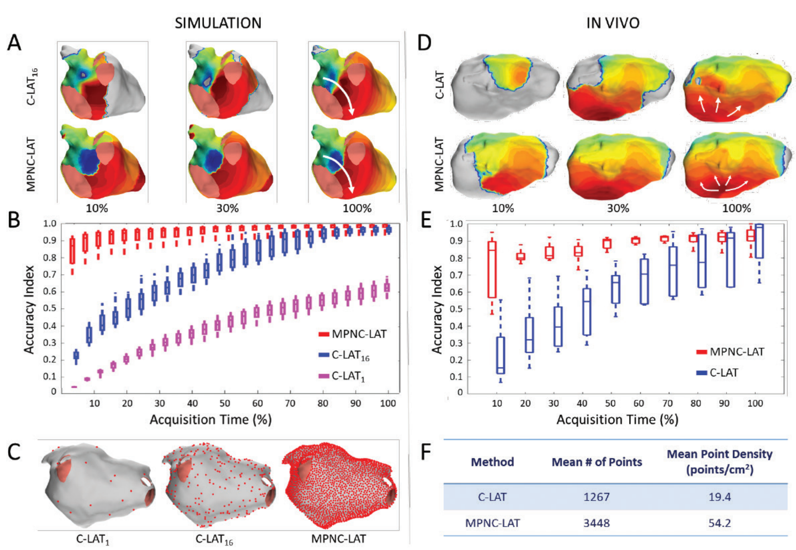
Methods: A cellular automata model was used to simulate 7 ATs and 3 AFLs including contact (C) measurements from 1 and 16-pole catheters and NC measurements on a 48-pole NC catheter. NC and C measurements were simulated at 25 CPs, each CP measured 1 cycle. *In vivo* NC and C measurements were also collected at multiple CPs in 5 PersAF patients who terminated via ablation to AT/AFL. All cycles were time aligned. A dipole density inverse solution used accumulated NC CPs to create a series of multi-position NC LAT (MPNC-LAT) maps – each map used a larger number of CPs. Complementary sets of C-LAT maps were also created.

Results: MPNC-LAT and C-LAT maps were compared using:

$$Accuracy\ Index\ (AI) = SA(1 - \frac{LAT\ Error}{CL})$$

LAT error was calculated as mean absolute error against the simulated LAT map (*in silico*)/final C-LAT map (*in vivo*). MPNC-LAT method required 64% less time *in silico* (40% *in vivo*) than C-LAT to achieve AI of 0.9. MPNC-LAT map has 7x denser points *in silico* (2-3x *in vivo*) compared to C-LAT. (*Figure* 1)

Conclusions: *In silico* and *in vivo*, the MPNC-LAT method quickly produces ultra-high-density maps of stable arrhythmias with high accuracy.



Method	Mean # of Points	Mean Point Density (points/cm²)
C-LAT	1267	19.4
MPNC-LAT	3448	54.2

A *C-LAT (16-pole) and MPNC-LAT maps of simulated RA-AT at 3 progressive time points.* **B** *Accuracy index vs. acquisition time across 10 simulated AT/AFLs for MPNC-LAT, C-LAT (16-pole), and C-LAT (1-electrode).* **C** *Example of spatial distribution of points for 1-pole C-LAT (26 points), 16-pole C-LAT (416 points), and MPNC-LAT maps (3696 points) (left-right).* **D** *In vivo C-LAT and MPNC-LAT maps of LA-AT at 3 progressive time points.* **E** *In vivo MPNC-LAT and C-LAT accuracy index vs. acquisition time across 5 AT/AFLs.* **F** *Table of average number of points and area point density across 5 in vivo AT/AFLs.*

RESEARCH

ACUTUS MEDICAL

ACQMAP CLINICAL COMPENDIUM

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Comparison of Charge Density and Voltage Recordings for Dominant Frequency Analysis during Atrial Fibrillation

HRS Abstract 2020 D-PO03-234. *Heart Rhythm* Vol. 17, No. 5, May Supplement 2020, S380.

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Background: Voltage based recording of intracardiac potentials have been the mainstay of electrophysiological studies but have limited spatial resolution owing to far-field interference. The electric fields measured by voltage recordings are created by localized differences in membrane charge and therefore direct measurement of Charge Density may reduce far-field effects. Previous investigations of AF using voltage recordings have demonstrated an overall Dominant Frequency (DF) driving this seemingly unstable rhythm.

Objective: To assess whether using Charge Density recordings for analysis of DF provides additional information compared to voltage.

Methods: Unipolar, non-contact, endocardial recordings of Charge Density and voltage were concomitantly collected from 28 patients in AF undergoing ablation procedures using the Acutus AcQMap system. Individual recordings from >3600 surface potentials were identically preprocessed by filtering, detrending and windowing, then analysed using Fourier transform to calculate spatially specific measures of DF and Regularity Index (RI). Atrial geometry was assessed using intracardiac ultrasound.

Results: Mean DF was significantly greater in Charge Density (10.3±0.4 Hz) compared with voltage (9.3±0.6 Hz, p=0.003) recordings. The smallest DF was similar between both Charge Density and voltage (5.1±0.7 Hz vs. 4.9±0.6 Hz, p=0.77), however the maximum DF was significantly higher in Charge Density recordings (14.3±0.6 vs. 12.9±0.4 Hz, p=0.036). RI was also greater in Charge Density compared with voltage recordings (0.14±0.004 vs. 0.12±0.004, p<0.0001), suggesting a lower degree of variation around the DF. Neither DF nor RI were altered by standard ablation procedures. Mean atrial volume was 166.3±8.0 ml and showed modest correlation with larger surface areas of endocardium with higher DF in Charge Density (R=0.41, p=0.032) but not voltage recordings.

Conclusion: DF is typically higher in Charge Density recordings, owing to an increased detection of higher DF values. This is potentially due to a greater ability to discriminate between regions with higher DF due to an increase in spatial acuity, which may have been masked by far-field contamination in voltage recordings.

Conduction Velocity of Left Atrial Electrical Charge Density

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Background: Endocardial conduction velocity (CV, m/s) of cardiac electrical activation has not been assessed globally.

Objective: The CV of the charge density (C/cm) in the entire left atrium (LA) was determined using non-contact charge density (NCCD) mapping.

Methods: Patients with persistent atrial fibrillation (N=6) and atypical flutter (N=2) underwent NCCD mapping procedure (AcQMap). Sinus rhythm (SR) was recorded pre or post ablation by roving the AcQMap catheter in the LA. NCCD maps were created from time-aligned AcQMap catheter positions according to a time reference. Peak spatiotemporal downstroke of CD was used to compute local activation time (LAT), and CV was computed using a polynomial fitting method. CV was also computed along the coronary sinus (CS) based on the LAT and the distance between the electrodes of a decapolar catheter.

Results: Figure 1 presents the CV and LAT map of the LA in SR. The arrows indicate the direction and magnitude of the CD propagation (blue to red). The CV ranges between 0.01 and 2 m/s. The LAT (grayscale) and isochrone are also displayed. In this example, the fastest CV region is located at left atrial appendage, septal-low-posterior LA and anterior LA. The CVs computed along the CS with LAT and distance ranges between 1.2 and 1.5 m/s, which corresponds to the CVs from the NCCD computed from the polynomial fitting method.

Conclusions: This study shows the feasibility to compute CV of the entire LA using a NCCD mapping system (AcQMap) and reveals preferential paths of electrical conduction in the atrium.

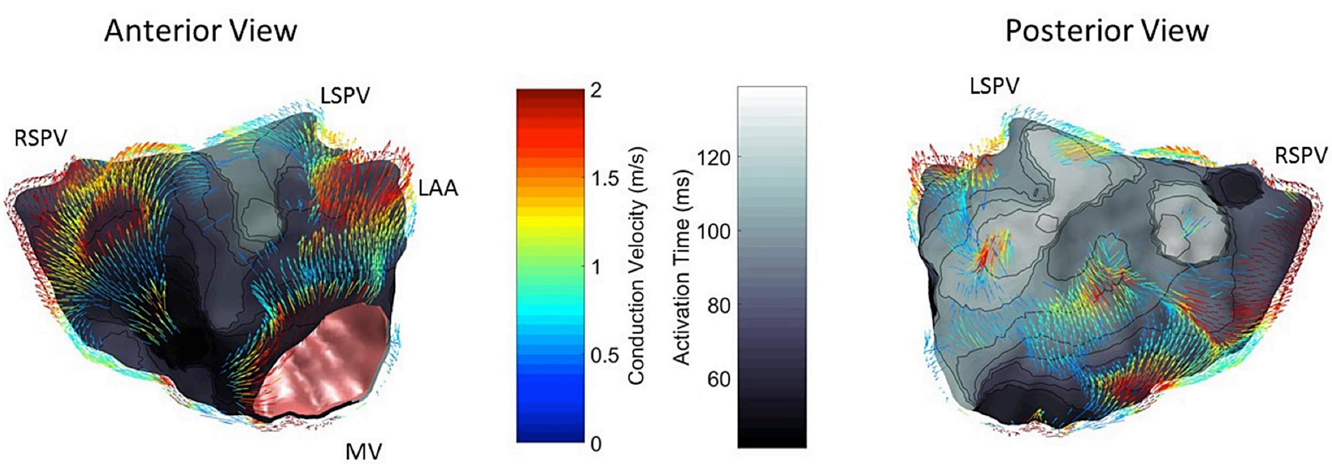

Figure 1: *Conduction Velocity and Activation Time Map (left atrium in sinus rhythm). The CV direction and magnitude are indicated by arrows with color coded (blue-red). Only CV between 0.5 and 2 m/s are displayed in the map. The activation time are grey color coded with isochrone displayed.*

Rotating Waves Cluster in Regions of Low Electrical Synchrony in Atrial Fibrillation

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Background: The significance of rotating waves (RWs) in maintaining AF remains controversial. Such an assumption requires spatio-temporal stability of RWs.

Objective: To assess rotation interpreted as a phase singularity and quantify its stability with a local electrical synchrony (ES) approach using data exported from a non-contact (NC) dipole density (DD) mapping system.

Methods: NC DD mapping was performed in left atria of 11 patients undergoing catheter ablation of persistent AF. 4 s recordings were analysed. Phase was calculated offline using custom software that employs sinusoidal recomposition and Hilbert transform. RWs were identified as phase singularity points with a lifespan > one cycle length. ES at each point was measured using a Mean Phase Coherence approach based on electrogram phases (0: no coherence; 1: full coherence).

Results: Mean AF cycle length was 202±35 ms (range: 132-281). In total, 248 RWs were identified (22.5±6.7 RWs/recording). At least one RW was present for 84±16% of recording time. The mean RW lifespan was 303±137 ms, with the longest 1150 ms. Areas of high RW density were co-localized with areas of low ES (see *Figure 1.a-b*). Point-by-point comparison between RW and ES demonstrated negative correlation with R2=0.24.

Conclusions: RWs were located in areas of lowest ES. Coupled with the short life span, it suggests that a stable RW is an unlikely conduction pattern for maintaining AF. The arrhythmogenic role of regions with a high density of short-lived RWs requires further study, including the role of coupling with other clinically significant conduction patterns.

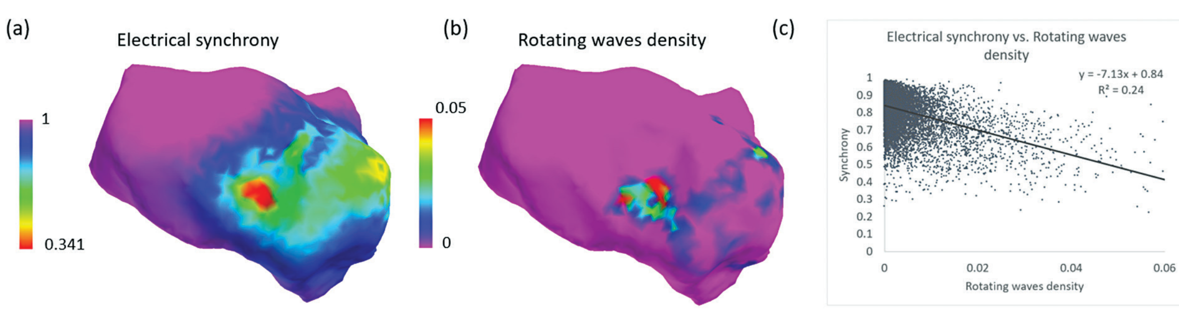

Figure 1. Example map of electrical synchrony (a) and rotating waves occurrence (b). Left Atrium, view of the septal area. Relationship between both measures for all data points and all patients (c).

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