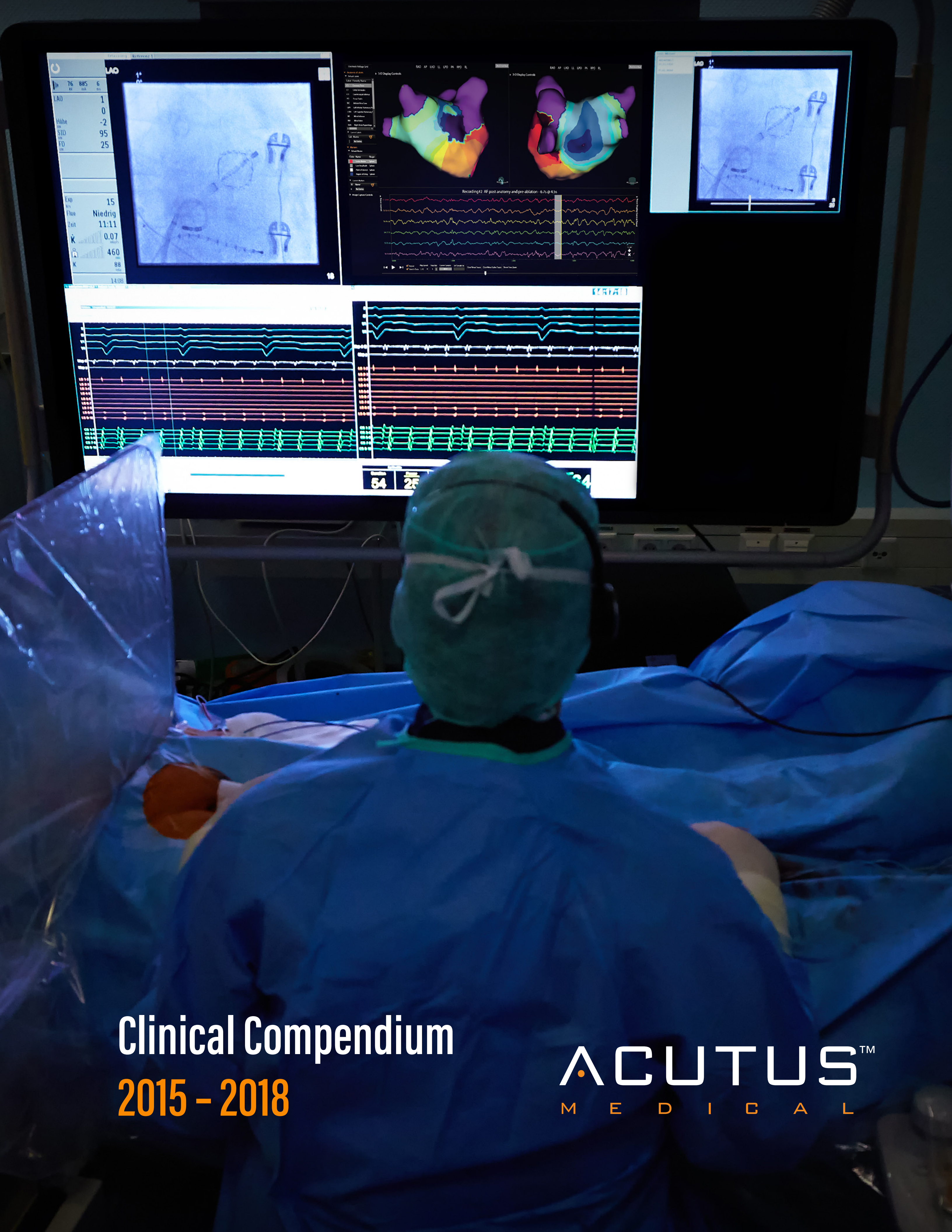


Clinical Compendium

2015 – 2018

ACUTUS™
MEDICAL

ACQMAP™

HIGH RESOLUTION IMAGING + MAPPING SYSTEM

NON-CONTACT AND CONTACT MAPPING FUNCTIONALITY

Map any rhythm — stable or unstable

CT QUALITY ANATOMIC RECONSTRUCTION

M-mode ultrasound acquisition[1] in non-contact mode

HIGHLY ACCURATE LOCALISATION AND NAVIGATION

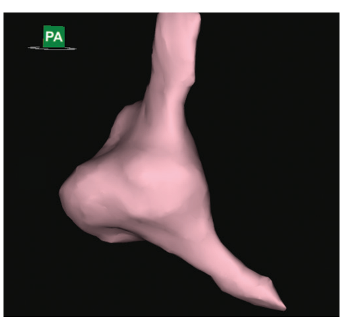
Visualise compatible diagnostic and therapeutic catheters

CHARGE DENSITY MAPPING

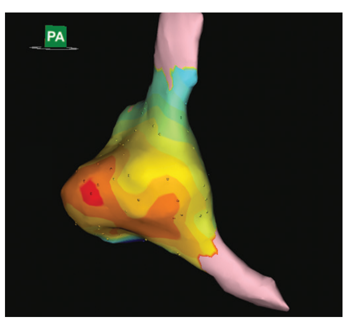
Four times higher resolution than voltage-based cardiac mapping[1]

EASILY MAP AND RE-MAP

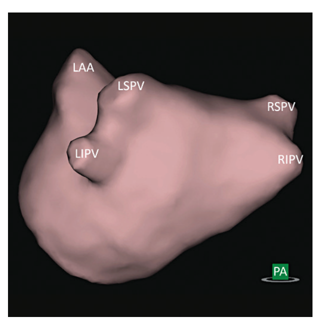
Reveals arrhythmic mechanisms to target pre- and post-ablation



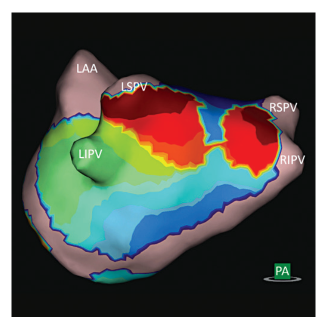
Contact right atrial anatomy



Contact map of CS pacing confirming isthmus block



Left atrial anatomy

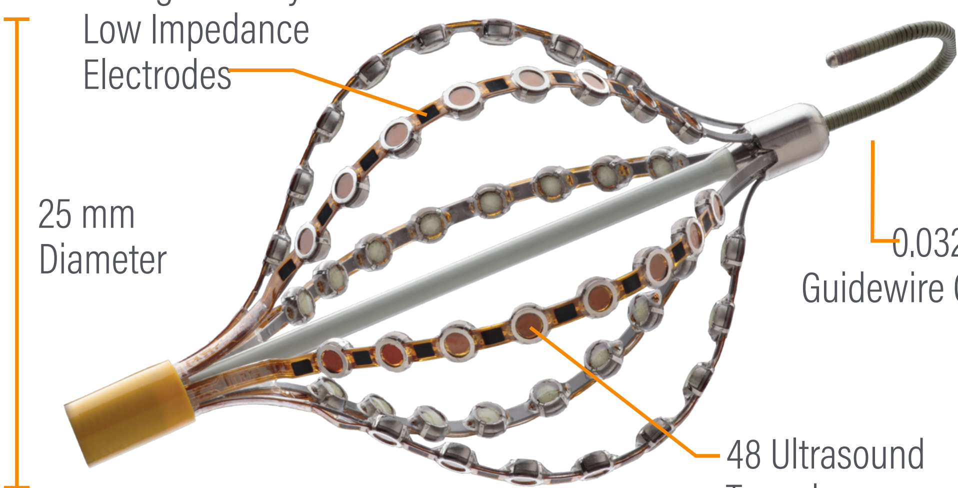


Charge density map of unstable atrial arrhythmia

[1] Patrick Heck, MD, PhD, et al. NOVEL GLOBAL ULTRASOUND IMAGING AND CONTINUOUS DIPOLE DENSITY MAPPING: INITIAL FINDINGS IN AF PATIENTS, HRUK Meeting, October 2015

ACQMAP™

3D IMAGING + MAPPING CATHETER



ULTRASOUND ANATOMY RECONSTRUCTION

Acquisition of up to **115,000 ultrasound data points per minute** for anatomy reconstruction

ULTRA HIGH RESOLUTION CHARGE DENSITY MAPS

Collection of up to **150,000 biopotential samples per second** for display of full chamber, real-time, high resolution cardiac electrical activity

OPTIMAL MANEUVERABILITY

Ease of maneuverability using the AcQGuide® MAX Steerable Sheath

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MEDICAL

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CASE STUDIES

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ACUTUS™
MEDICAL

Individualized Ablation Strategy Guided by Live Simultaneous Global Mapping to Treat Persistent Atrial Fibrillation

Future Cardiol. 2018; 14(3), 237–249

Rui Shi, Mark Norman, Zhong Chen & Tom Wong, Heart Rhythm Center, The Royal Brompton & Harefield NHS Foundation Trust, National Heart & Lung Institute, Imperial College London, London, UK

Background: Atrial fibrillation (AF) is the most common clinical arrhythmia encountered. Catheter ablation has become the first-line therapy for symptomatic drug-refractory paroxysmal and persistent AF.

Evolution of AF ablation & the challenges of persistent AF: Although pulmonary vein electrical isolation is still the cornerstone of the ablation strategy, the clinical outcome particularly in treating persistent AF is suboptimal. Conventional contact and noncontact voltage-based mapping may not adequately identify patient-specific drivers and/or maintainers of AF due to their spatially averaged representation of the actual complex and irregular spatiotemporal characteristics of cardiac conduction. In the last decade, significant efforts and intense research have been incorporated into newer mapping systems to improve procedural efficiency and outcomes for AF ablation. Accurate panoramic live mapping of AF is a novel approach that may lead to an increasingly successful outcome of ablation. There are several fundamental and important requisites in understanding the complexity of persistent AF, so clinicians can target optimal ablation sites to treat persistent AF. They include an accurate anatomic surface mesh and accurate live mapping of the dynamic rapidly changing wave fronts. Identification and understanding of fibrillatory circuits is a formidable challenge but success for ablation also requires effective ablation lesion delivery to achieve transmural and durable lesions in the targeted location.

Noncontact endocardial mapping with EnSite® Array: The first noncontact, global chamber mapping technology used 64 unipolar electrodes to record cavitary virtual unipolar electrograms and display these calculated electrograms on a surface mesh.

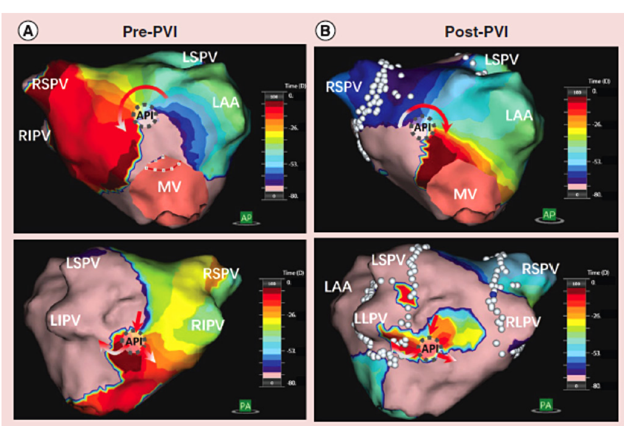
Contact focal impulse and rotor modulation phase mapping: The technology identified sites of spiral rotors and focal drivers of AF in humans for the first time by using a 64-electrode contact mapping basket catheter to collect electrophysiologic activity.

Noncontact body surface mapping: A noninvasive mapping system that uses 252 external electrodes in combination with computed tomography to record bi-atrial unipolar electrograms and create simultaneous bi-atrial 3D maps.

Novel noncontact charge density mapping: The AcQMap® catheter has ultrasound transducers interspersed between biopotential electrodes. Ultrasound is used to image and reconstruct the endocardial surface. The intracardiac potential field is measured by the biopotential electrodes. Charge density represents the actual biophysics of cardiac activity and is a more localized entity that provides a more focused view into the details of cardiac activation.

Future perspective: The next phase in AF mapping will depend heavily on advancing fundamental knowledge of arrhythmia mechanisms in humans. Increasing success will depend upon the ability to simultaneously map temporal, spatial and high-resolution electrogram data accurately to target both non-PV triggered and complex persistent AF. The emergence of global chamber, live mapping systems may help us to accurately identify clinically critical non-PV targets for ablation. Future clinical studies are required to investigate if these novel mapping technologies such as noncontact dipole density mapping can provide a better understanding of the mechanistic characterization of AF and individualized ablation strategies that relate to an improved clinical outcome.

Conclusions: Within this review, we present an overview of contemporary global chamber AF mapping technologies and characteristics, with a focus on global, noncontact, charge density mapping illustrated with a clinical case of persistent AF ablation using this novel methodology.[3]



Initial pre- and postpulmonary vein electrical isolation propagation history map in persistent atrial fibrillation. Two spatial and temporal consistent API located on middle anterior wall (AP view) and on the lower posterior wall (PA view) pre-PVI (A) and post-PVI (B), respectively.

AP: Anterior-posterior view; API: Atrial activation pattern of interest; LIPV: Left inferior pulmonary vein; PA: Posterior-anterior view; PVI: Pulmonary vein electrical isolation.

Novel Multipolar Mapping System Identifying Coexistence of Multiple Conduction Patterns in Persistent AF: A Case Report

Pacing Clin Electrophysiol. 2017:1-4. DOI: 10.1111/pace.13132

Conti S, Giewercer D, Whaley B, Verma A. Southlake Regional Healthcentre, Newmarket Ontario, Canada and University of Toronto, Toronto, Ontario, Canada.

Introduction/Objectives: PVI alone has led to suboptimal outcomes in persistent AF (persAF) prompting physicians to look at more mechanistic, non-PV ablation strategies to complement. We report the use of a novel invasive, noncontact imaging and mapping system to identify activation patterns and location of sources in a persAF patient.

Methods: A 50-year-old male with episodes of persAF since 1998 was consented for AF catheter ablation. Medications included rivaroxaban, flecainide, and pantoloc. The patient arrived to the procedure in SR after having been recently cardioverted.

Results: Following transseptal puncture, the patient was heparinized with an ACT target of 350s. The patient was induced into AF using the lab's standard pacing protocol. The AcQMap catheter was deployed in the LA and ultrasound was activated to collect points and reconstruct the chamber anatomy. A pre-PVI map of AF was created. (Figure 1) The map showed non-PV focal breakthrough and confined zones of localized rotational activation anterior to the right PV antrum and between the inferior aspect of the right and left PV antra. Repetitive focal firing adjacent to rotational activation on the posterior wall and septumwas also seen. Based on the information in the map, a wider encircling of the PVs was performed to include the focal sites adjacent to the two zones of interest. Another AcQMap of the LA was obtained showing a different pattern of activation at approximately the same locations as in the pre-PVI map. A progressive ablation strategy was proposed targeting both confined zones of localized irregular activation and anchoring them to the adjacent PVI line. The right PV antrum was targeted first at its center and then attached to the encircling lesions around the right superior pulmonary vein. Then, an ablation line was created to connect the PVI lines around the right and left inferior PVs. The patient was then cardioverted to SR. Entrance block was demonstrated into all four PVs and block was seen below the posterior ablation line with mapping during SR. To date, after 6-months follow-up, the patient remains in SR with no recurrences and off AADs.

Conclusions: The ability to quickly and repeatedly map a limited number of mechanisms is new. While there is much to learn about these confined zones of complex activation, it is encouraging that, in addition to a finite number of commonly seen activation patterns, the mechanisms described here appear to be closely related to well-known arrhythmogenic mechanisms that are responsible for less complex arrhythmias, such as focal and reentrant tachycardias.[5]

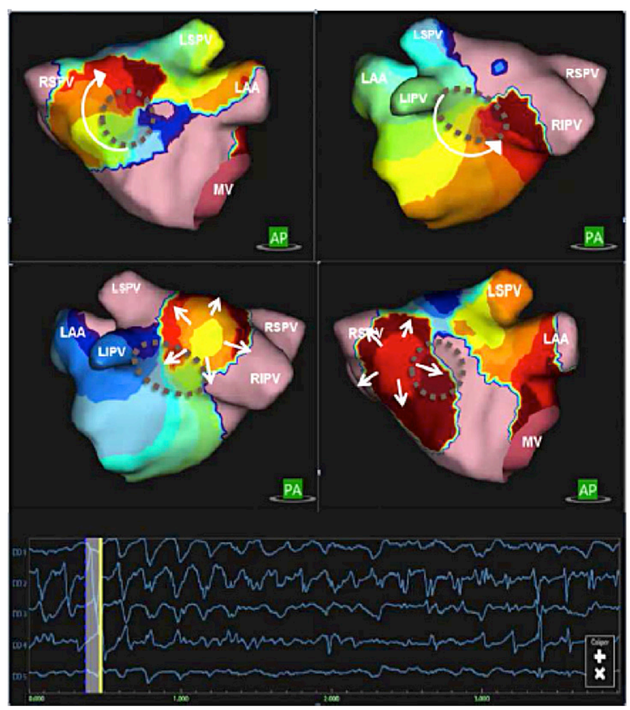


Figure 1 Pre-PVI AcQMap of AF. Panel A shows localized rotational activation just anterior to the RSPV. Panel B shows another localized rotational activation between the LIPV and RIPV. Panel C shows a focal breakout just adjacent to the posterior localized rotation. Panel D shows a focal breakout just adjacent to the anterior localized rotation. Panel E shows the reconstructed electrograms over the 4 seconds of the continuous AF recording.

VALIDATION

Novel Ultrasound and Dipole Density Mapping: A Feasibility Study in Patients with Atrial Flutter

HRS Abstract P004-82. *Heart Rhythm*, Vol. 12, No. 5 May Supplement 2015 S349
Europace 2015 Abstract P1426 *Europace* Vol 17, Issue suppl 3 June 2015 (Pp iii205 – iii228)

Mattias Duytschaever, MD, PhD, Stephan Willems, MD, PhD, Rene Tavernier, MD, PhD, Boris Hoffman, MD, Yves Vanderkerckhove, MD, Sint-Jan Hospital Bruges, Department of Cardiology, Bruges, Belgium and Department of Electrophysiology, University Heart Center, University Hospital Eppendorf, Hamburg, Germany.

Introduction: The electrical field (Volt, V) has been used to map arrhythmias. The sources of this field are local charge or dipole density (DD).

Methods: A novel non-contact mapping system (AcQMap), consisting of a basket catheter (48 ultrasound (U/S) crystals, 48 electrodes) and console, measures cardiac V and uses an inverse DD algorithm to display electrical activation as DD maps on an ultrasound (U/S) constructed 3D anatomy in real time. Patients undergoing flutter ablation were consented for AcQMap. DD and V maps were created for each patient and depolarized surface areas were compared.

Results: Eight patients (mean age 59 years) were enrolled. U/S data were acquired in 5 patients with CT quality reconstructions of chamber anatomy. V and DD maps were obtained for sinus rhythm, septal and lateral pacing, AFL (*Figure 1*). During AFL, mean depolarized area for DD was 17.3 cm^2, significantly less than for V (71.1 cm^2, $p<0.0001$). Overall DD:V ratio was 0.24 for AFL; 0.21 for SR; and 0.22 for pacing.

Conclusion: AcQMap provides a DD map with 4.1 times as high resolution as V maps, and represents them on CT quality anatomy. This opens the possibility to map irregular arrhythmias with more precision.

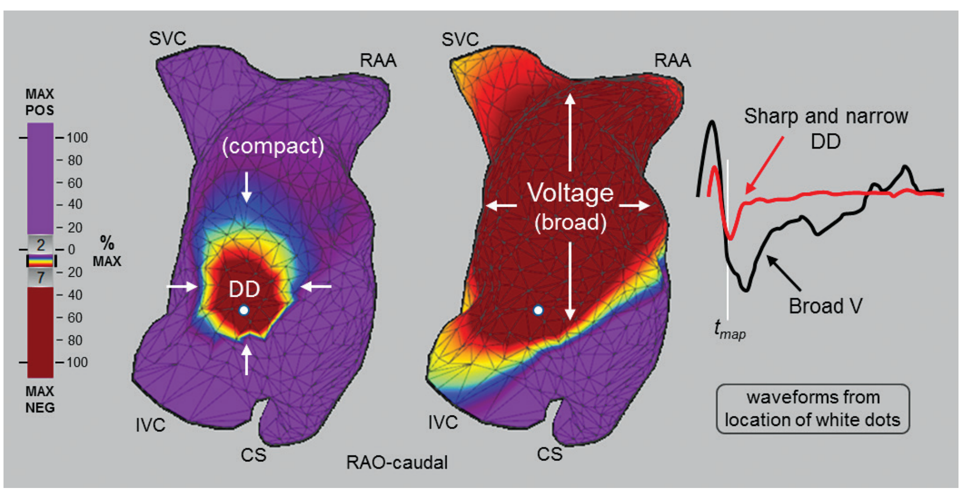


Figure 1. Area of depolarization for DD vs V at one instant during AFL

Application of Dipole Density versus Voltage in Electrophysiology: A Model Study

Europace 2015 Abstract P1042 *Europace* Vol 17, Issue suppl 3 June 2015 (Pp iii136 – iii159)

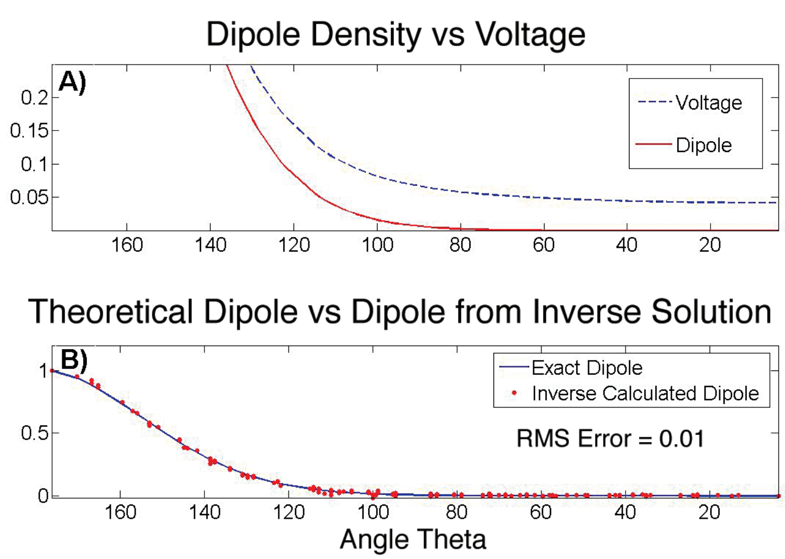
Lam Dang, PhD, Graydon Beatty, PhD, Gunter Scharf, PhD. Klinik im Park, Zurich, Switzerland, Acutus Medical, San Diego USA and Physics Institute, University of Zurich, Switzerland

Introduction: Voltage (V) measured with direct contact is believed to be the best measure of cardiac activation. V is a far-reaching summation of the local positive and negative sources of charge that propagate across the myocardium from the action of ion channels. It is clinically desirable to measure these local sources.

Methods: Local sources were modeled as a double-layer of Dipole Density (DD) on the endocardial surface (ES) with orientation of DD perpendicular to the ES. A sphere (radius=1) was used to model the ES and the function exp(αcosθ) to model DD on the ES (DD=1 at the South Pole of the ES and exponentially decreasing to 0 at the North Pole). Exact V can be calculated everywhere for this model. V was calculated across the ES and applied in a DD inverse algorithm that reconstructed DD on the ES. Reconstructed DD was compared to the exact model of DD.

Results: V on the ES reached beyond the DD sources, with a long rightward tail, compared to the finite range of DD (*Figure 1A*). The RMS error between the reconstructed DD and the exact model of DD was 0.01 (1%) across the entire ES (*Figure 1B*).

Conclusions: This model demonstrates the basic feasibility of inverse reconstruction of DD on the ES from an array of non-contact measurements of V and opens the possibility of high resolution global mapping without the challenges of maintaining direct contact. Further study on human anatomy with biologic sources is warranted.



Novel Global Ultrasound Imaging and Continuous Dipole Density Mapping: Initial Findings in AF Patients

Heart Rhythm UK 2015 Abstract *Europace* Vol 17, Issue suppl 5 October 2015
American Heart Association Abstract A17111 *Circulation*. 2015;132

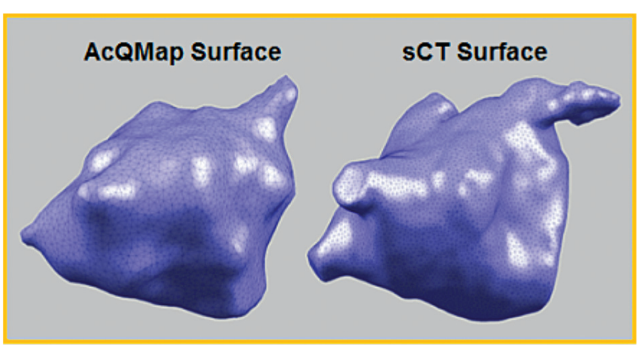
Patrick Heck, MD, PhD, Andrew Grace, MD, Vivek Reddy, MD and Petr Neuzil, MD, Papworth Hospital, Cambridge, UK, Mount Sinai School of Medicine, New York, NY and Homolka Hospital, Prague, Czech Republic.

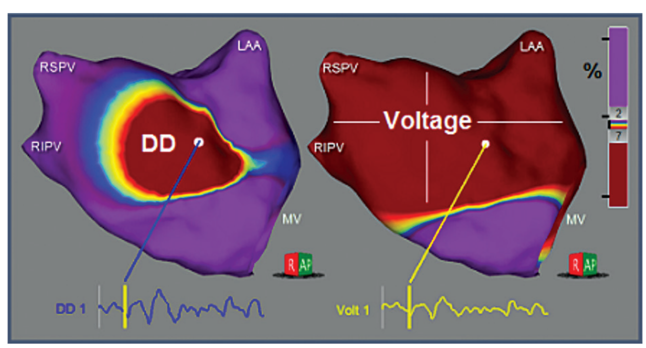
Introduction: Electro-anatomic mapping is standard practice in AF ablation procedures. Virtual anatomies are created to locate structures and navigate catheters and voltage (V) is used to map arrhythmias.

Methods: A novel non-contact imaging and Dipole Density (DD) mapping system (AcQMap), consisting of a basket catheter (48 Ultrasound (U/S) transducers, 48 electrodes) and console, simultaneously acquires 100,000+ U/S points/min to reconstruct the chamber anatomy and 150,000 intracardiac unipolar V samples/second to map cardiac activity. The 3D surface is algorithmically reconstructed from the U/S point-set with mesh-density comparable to segmented CT (sCT). Inverse and Forward algorithms are applied on intracardiac V to derive and display activation as DD and unipolar V maps, respectively, upon the U/S-constructed 3D anatomy (Figure). Patients slated for AF ablation were consented for U/S and DD mapping. U/S LA anatomy was created from full and sub-sampled point-sets and compared to pre-procedure sCT. DD and V maps were derived for each patient and depolarized surface areas were compared.

Results: Seven patients (57% Male, Age 61.4 ± 10.3 yrs, AF duration 4.2 ± 2.3 yrs) were enrolled. Complete data sets were collected in 6 subjects. Surface-points must be acquired for at least 30 seconds to achieve a consistent median distance between AcQMap and sCT surfaces. The absolute median distance between surfaces was 2.71 mm. During AF, the mean depolarized area for DD maps was 26.9 cm^2, significantly less than for V maps (110.6 cm^2, $p < 0.001$). Overall V:DD ratio was 4.11 for AF.

Conclusions: Real-time U/S based LA reconstruction was rapid and compared favorably to sCT. DD map provides 4.11 times higher resolution than V maps. The combination of CT-quality anatomy and DD mapping opens the possibility to map AF with more precision to identify areas of interest as potential ablation targets.





Noncontact Dipole Density Mapping of Complex Atypical Flutters using an Ultrasound-Electrode Array Catheter: Comparison to Conventional Contact Mapping

HRS Abstract P003-103. ***Heart Rhythm*****, Vol. 13, No. 5 May Supplement 2016 S292**

Vivek Reddy, Mount Sinai School of Medicine, New York, NY.

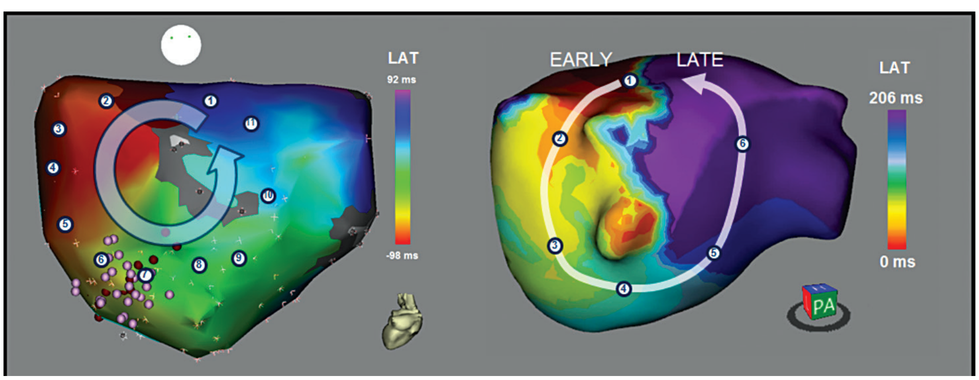
Introduction: Conventional contact mapping (CM) of atypical atrial flutter (AtyFL) requires high density. Non-contact, global, dipole density mapping (ddNCM) partly obviates the technical skill needed for high density CM mapping. Dipole density derives the local charges sources on the surface from cavitary voltage, an approach that should minimize far-field effects. We assessed AtyFL mapping using a novel ultrasound (U/S) basket catheter able to perform ddNCM.

Methods: The AcQMap system (Acutus Medical Inc) employs a basket catheter [25 mm dia, 48 U/S crystals (m-mode), 48 electrodes] that rapidly acquires endocardial U/S points to render LA-PV anatomy, and then computes ddNCM. These ddNCMs were compared to conventional CM.

Results: The study cohort included 11 pts: age 64.7±5.8 yrs; 64% male; LA 49.8±3.5 mm; HTN-91%, DM-27%, Hx CVA-9%, Vasc Dz-9%; prior ablation-64%; arrhythmia duration 4.7±4.6 yrs;

Rhythms AtyF-100%/AF-91%. AtyFLs were observed in 11/11 pts (total of 22 AtyFLs; mean CL 312±84ms, range 206-567). All AtyFLs were mapped with both ddNCM and CM. The AtyFL CLs were stable in the first 4 patients, with good correlation among all map types. In the final 7 patients, multiple, complex, and irregular rhythm patterns were observed for which CM was able to map 13% and ddNCM 100%.

Conclusions: In stable rhythm patterns there was good agreement among all map types. In more complex, irregular rhythms CM was unsuccessful, whereas ddNCM successfully identified the pattern for all mapped AtyFLs.[9]



Isochronal activation map for conventional contact map (left) and noncontact dipole-density map (right). The dipole density map reveals more detail in the conduction pattern than the conventional voltage-based map.

Rapid 3D Reconstruction of the Left Atrium using a Novel Non-Contact Ultrasound Array Catheter in Patients Undergoing Left Atrial Ablation

Cardiostim Abstract. *Europace* **Vol 18, Issue Supplement 1 June 2016 189-06, i139.**

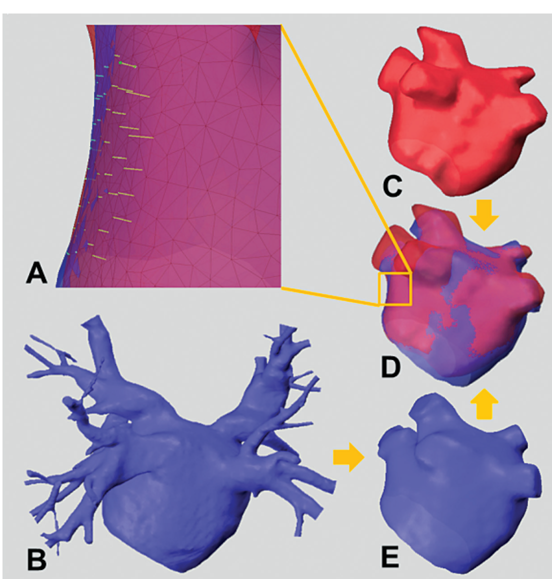
Petr Neuzil, Vivek Reddy, Patrick Heck, Andrew Grace, Jana Nührich, Boris A. Hoffmann, Stephan Willems. Homolka Hospital, Prague, Czech Republic, Mount Sinai School of Medicine, New York, NY, Papworth Hospital, Cambridge, UK, University Hospital Eppendorf, Hamburg.

Introduction: Electroanatomic 3D mapping systems that employ registration of segmented CT (sCT) images are effective in rendering the LA and PV anatomy veins but require substantial technical skill by the operator. We tested the accuracy of ultrasound (U/S) chamber reconstruction using a basket catheter system able to both rapidly image and globally map the LA.

Methods: The AcQMap system (Acutus Medical Inc) employs a basket catheter [25 mm dia, 48 U/S transducers (m-mode), 48 electrodes] that acquires 100,000+ endocardial U/S points/min. The operator maneuvers/rotates the catheter in the LA. Algorithms filter and decimate the point set into a 3D surface with a mesh density comparable to sCT. The 3D LA anatomy is reconstructed from these U/S point sets.

Results: In 16 pts undergoing LA ablation (age 62.7±8.4 yrs; 75% male; LA 43.7±6.5 mm; rhythm AF-12/AFL-2/both-2; prior ablation in 7), 3D AcQMaps were compared to pre-procedure sCTs. The absolute median distance between AcQMap and sCT surfaces was 1.86 mm ± 2.62. Mean U/S acquisition time was 7.4 ± 3.5 min for the full cohort; a 14% reduction (6.2 ± 2.3 min) occurred in the last 7 subjects

Conclusions: Real-time U/S-based 3D LA reconstruction was facile, rapid and the 3D anatomy compared favorably in quality to sCT. While algorithmic refinements are likely to further improve the quality of the 3D LA-PV anatomy, the current reconstruction provides discernable PV ostia and anatomic landmarks required for ablation guidance.



*AcQMap anatomy (**C**) comparison to sCT.*

*Pre-procedure sCT (**B**) is trimmed (**E**) and registered to the AcQMap anatomy (**D**).*

*Surface distances are measured along the surface normals from AcQMap anatomy to the point of intersection on the sCT (**A**).*

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Dipole Density versus Voltage-Based Mapping in Atrial Fibrillation: What can be Uncovered?

HRS Abstract C-PO05-85. *Heart Rhythm*, **Vol. 14, No. 5, May Supplement 2017. p S455**

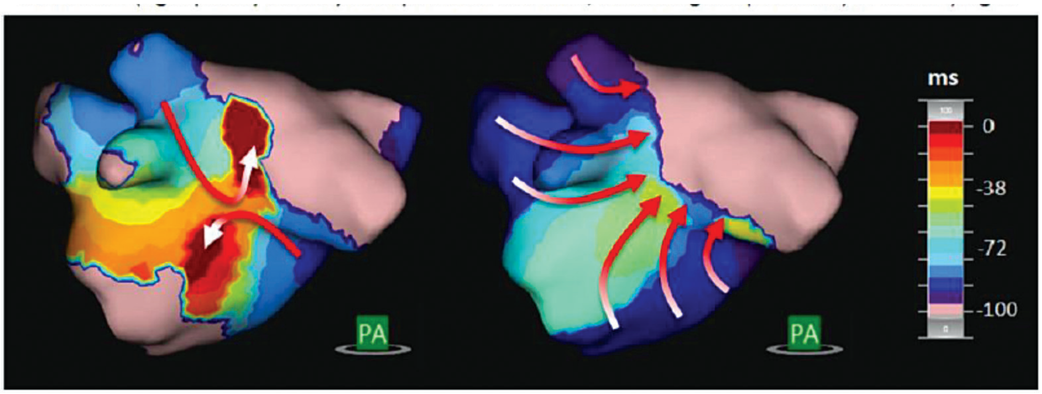
Atul Verma MD, FHRS, Stephan Willems MD, PhD. Southlake Regional Health Centre, Newmarket, Ontario, Canada, University Heart Center, Hamburg, Germany.

Background/Objectives: Voltage-based 2D and 3D mapping systems have shown focal and rotational mechanisms to be present during AF. However, the broadness of the voltage field may obscure other possible mechanisms. A new, non-contact, 3-D imaging and mapping system capable of displaying either voltage (V) or dipole density (DD) was used to compare the type and incidence of AF mechanisms (AFMs) identified from the same data segment.

Methods: Patients were mapped prior to ablation using a 6-splined catheter with 48 U/S crystals and 48 electrodes. LA chamber anatomies were acquired using U/S. The same 4-s segment of raw AF data was processed and displayed as both DD and V. DD is inverse-calculated to subtract distant sources and globally display localized, raw activation data (no phase mapping) to highlight arrhythmic drivers and maintainers. Independent reviewers identified AFMs in DD and V maps classifying them as Focal, Rotational and Irregular.

Results: A total 15 pts were enrolled at 2 sites. Male 93%; Age 59 yrs; PersAF 93%; AF duration 4.6 ± 4.6 yrs; LAD 44.0 ± 4.5mm. A total of 38 AFMs were identified in the V maps and 92 AFMs in the DD maps ($p = 0.002$). AFM summary of V vs DD was Focal 7 vs 19; Rotational 23 vs 29 and Irregular 8 vs 44. The Irregular AFM was significantly more-often visible in DD maps ($p < 0.0001$). (*Figure 1*)

Conclusions: DD mapping identified more total AFMs than V in the same AF data segments. The broadness of V was apparent in the maps which likely obscured the identification of the Irregular AFM. A clinical study is underway to evaluate the effect of ablation on AFMs identified by DD.



Two narrow Dipole Density wave fronts (left panel) enter a localized "Irregular" AFM zone from opposite directions and exit in two other directions. At the same time-instant, a single Voltage wave front (right panel) broadly sweeps across the zone, obscuring the possibility of identifying it.

MAPPING STABILITY

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Novel Ultrasound-based Imaging and Global Dipole Density Mapping: Feasibility in Persistent Atrial Fibrillation

HRS Abstract P003-106. *Heart Rhythm*, Vol. 13, No. 5 May Supplement 2016 S293

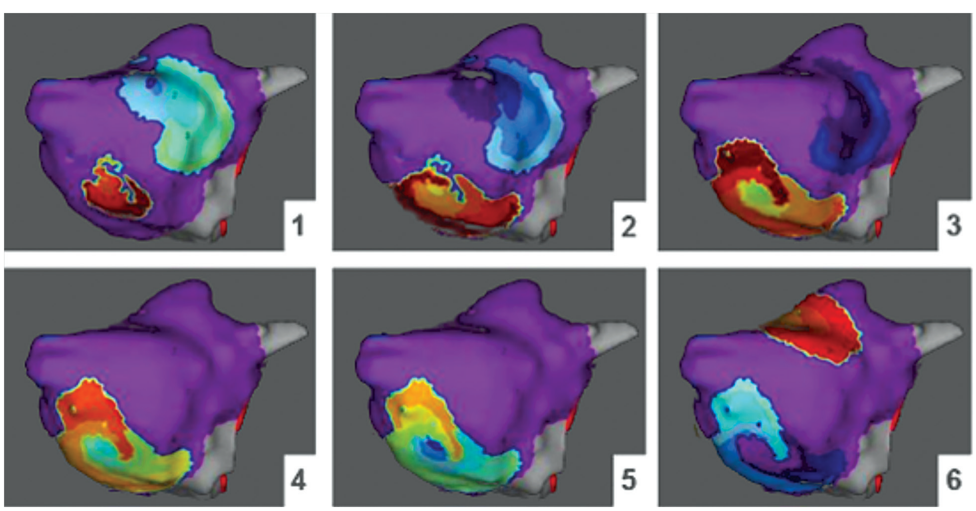
Jana Nührich, Julia Moser, Benjamin Schäffer, Ruken Özge Akbulak, Mario Jularic, Christian Eickholt, Pawel Kuklik, Christian Meyer, Boris A. Hoffmann, Stephan Willems Department of Electrophysiology, University Heart Center, University Hospital Eppendorf, Hamburg

Introduction: Contact electrograms are the diagnostic norm. AcQMap (Acutus Medical, San Diego, CA) derives the local charge-sources (dipole density (DD)) from noncontact voltage and displays them as a color map on a 3D ultrasound (U/S) reconstructed anatomy.

Methods: Patients scheduled for AF ablation were consented and mapped using a basket catheter with 48 U/S crystals and 48 electrodes. DD is inversely calculated to subtract the effect of distant sources and display a more localized map of activation. Conduction is displayed as a retrospective moving color-map. Red is the present location of the leading-edge, while other color-bands represent earlier locations in time (*Figure*). Historical persistence of the leading edge enables visualization of complex conduction patterns. U/S anatomies and pre-/post-ablation maps were obtained.

Results: Four patients were enrolled (age 57 (52-62), BMI 29 (26-36), AF 3 years (2-4)). A total of 41 intervals of left atrial AF (33.7 s) were mapped in the 4 patients. Multiple waves spread out from focal sites and short-lasting zones of rotation. A common theme of higher complexity was observed in the septum and the region between the antral junctions of the pulmonary veins, including irregular short-radius reentry and patient specific central paths of rotation.

Conclusion: U/S-based imaging and DD mapping is feasible in Persistent AF. It may enable more detailed visualization of propagation patterns and potential therapeutic targets. Further clinical studies are needed to determine clinical benefit.



Propagation pattern at six instants of time in the left atrium during AF with irregular short-radius reentry in the septal region. Red represents the present location of the leading-edge, while the other color-bands represent its location at earlier steps of time.

Mapping Stability with Ultrasound-Based Imaging and Dipole Density Mapping in Patients with Persistent Atrial Fibrillation

HRS Abstract C-PO06-45. *Heart Rhythm*, **Vol. 14, No. 5, May Supplement 2017. p S531.**

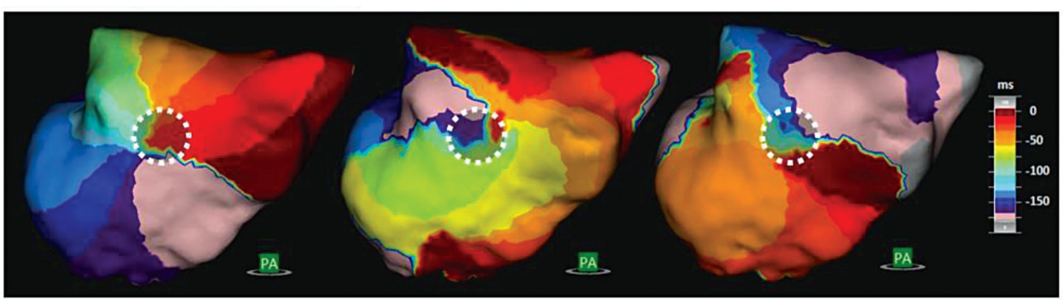
Jana Nührich, Julia Moser, Benjamin Schäffer, Ruken Özge Akbulak, Christian Eickholt, Pawel Kuklik, Christian Meyer, Stephan Willems

Background: Characterizing the LA in persistent AF (persAF) remains challenging. A new, non-contact, 3-D imaging/mapping system uses ultrasound (U/S) to acquire chamber anatomy and globally map localized dipole density (DD) charge-sources instead of the broader voltage-field.

Methods: Pts scheduled for a first ablation of persAF were mapped using a catheter with 48 U/S transducers and 48 electrodes. U/S anatomies were acquired and 4 sec segments of AF were mapped. DD is inverse-calculated to subtract distant sources and globally display localized, raw activation data (no phase mapping) to highlight arrhythmic drivers and maintainers. Ultrasound-based chamber anatomy and DD activation data was mapped from AF before, and remapped during and after pulmonary vein isolation (PVI). Ablation was continued at sites identified as critical by DD mapping.

Results: Ten patients were enrolled (age 63 (47-76) years, BMI 28 (23-33) kg/m2, AF history 8 (3-15) months). One patient was on amiodarone. U/S-based anatomy and DD maps were successfully acquired in all patients. Three critical mechanisms were observed: Focal; Rotational; and Irregular. AFCL was not affected by PVI, but increased after ablation of critical DD sites (160 (130-210) ms vs 200 (140-260) ms). Thirty maps were generated in AF and 31 critical sites were identified. Location of critical sites remained stable over the total duration (*Figure*). No device related complication occurred.

Conclusion: DD mapping of persAF is feasible and reproducible. It may enable stable visualization of sites critical for driving and maintaining AF and for targeting ablation therapy.



Sites	31
Focal	10
Rotational	42
Irregular	93
Time Span (min)	48.35 ± 41.80
Stability Factor	0.96 ± 0.14
	perfectly stable = 1.00

Stable site of AF maintenance spanning 104 minutes.

Site captured at 3 time-points reveals both Rotational (pictured) and Irregular mechanisms of activation that sequentially alternate ("couple") through time.

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Spatial Stability and Consistency of Dipole Density Mapping (AcQMap®) in Persistent Atrial Fibrillation

HRS Abstract B-PO04-105. *Heart Rhythm*, **Vol. 15, No. 5, May Supplement 2018, S432.**

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Background: A coherent display and comprehension of persistent AF (persAF) remains challenging. AcQMap® is a new non-contact unipolar high-resolution system using a spheroid-shaped AcQMap® catheter (AC) providing 48 ultrasound transducers and 48 electrodes for 3D anatomy reconstruction and continuous dipole density (DD) charge-source mapping instead of broader voltage-field for displaying AF wave fronts.

Aim: We sought to evaluate the spatial distribution and stability of the displayed AF wave fronts in a two-center study.

Methods: Data was obtained from patients with persAF in two centers (Cologne and Hamburg) using the AC for 3D anatomy and DD AF maps were analyzed. Wave front propagation was characterized into 3 predefined patterns of conduction: 1. focal, 2. rotational and 3. irregular.

To analyze the distribution and particularly the consistency of recorded wave conduction patterns, maps were evaluated at 3 different time-points prior to ablation. To obtain a consistency factor, the type and number of recorded patterns were allocated to specific left atrial (LA) sites identified in each of the maps. Consistency was scored on the extent to which the patterns persisted at the identified sites across all 3 time-points.

Results: For all 20 patients (10/center) AC based anatomy and DD maps were successfully acquired. A total of 77 sites in 60 recorded DD maps were analyzed. The average analyzed time span was 53.9 ± 34.0 min per patient. Evaluation of DD maps showed a total number of 30 focal, 96 rotational and 149 irregular AF conduction patterns. The overall spatial consistency factor for displayed patterns was 0.7±0.3 (1=perfectly consistent).

The posterior wall (n=30), LA roof (n=21) and septal LA (n=14) were identified as predominant sites for locations of pivotal patterns. Less frequent sites were the anterior, lateral and inferior LA (total n= 12). Comparison of the predominant sites revealed that the irregular and the rotational AF conduction patterns were most frequent at the posterior LA wall (n= 58; n=43 vs. n=40; n=23 (LA roof) vs. n= 32; n=15 (septal LA)). A focal pattern was more frequently revealed at the LA roof (n=13 vs. n=8 (posterior wall) vs. n=4 (septal LA)). Furthermore, a consistency factor <0.7 was associated with an altered average number of LA sites with detectable conduction patterns (5 (3-7) vs. 3 (2-4)). A high consistency factor of 0.85±0.3 was seen for the irregular conduction pattern vs. 0.6±0.3 for a rotational conduction pattern and 0.4±0.2 for a focal pattern. No device related complications occurred.

Conclusion: DD maps of persAF reveal a very high spatial consistency and stability of detected AF conduction patterns. Such reproducible visualization of pivotal sites of the arrhythmia may facilitate ablation of persAF.

CLINICAL OBSERVATIONS AND RESULTS

Initial Procedural Results from the DDRAMATIC-SVT Study: AF Mechanism Identification and Localization using Dipole Density Mapping to Guide Ablation Strategy

AHA Abstract A17822, *Circulation* Vol 134, Issue Supplement 1 November 11, 2016

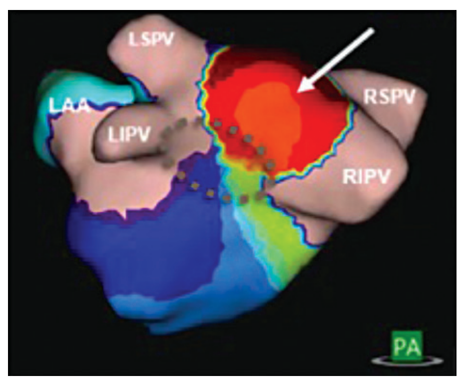
Andrew Grace, Vivek Reddy, Petr Neuzil, Stephan Willems, Atul Verma, Richard Schilling, Pier Lambiase, Mark Hall for the DDRAMATIC-SVT investigators.

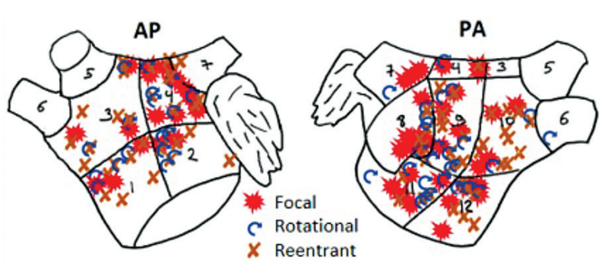
Introduction: DDRAMATIC-SVT is a prospective non-randomized study to demonstrate safety and performance of a novel imaging/mapping system to reconstruct cardiac chambers using ultrasound (U/S) and globally map the atrial endocardial surface using dipole density (DD) to identify mechanism(s) and location(s) of atrial tachyarrhythmias.

Methods: Patients with PrAF scheduled for ablation were mapped using a basket catheter with 48 U/S crystals and 48 electrodes. DD is inversely calculated to subtract the effect of distant sources and display a more localized map of activation. Conduction is displayed as a retrospective moving color-map. Red is the present location of the leading-edge, while trailing color-bands represent earlier locations in time. U/S anatomies and ~4 sec segments of AF were mapped to identify mechanisms and locations. Pulmonary vein isolation/touch-up was performed followed by mechanistically targeted ablation.

Results: A total of 6 sites enrolled 27 patients between Jan-May, 2016. (Available data: Mean age 60.7 yrs, 78% Male, AF duration 5.2 ± 4.7 yrs, 37% redo, 26% amiodarone, LA diameter 44.5 ± 6.1 mm). A total of 167 mechanisms were identified in pre-ablation maps. Mechanisms included 28.7% rotational activation (≥180 degrees), 31.1% focal (≥3 firings/map), 40.2% irregular reentry (entry/exit in confined zone). Average number of mechanisms/patient was 6.2. Number of mechanisms and average fibrillatory CL listed in *Figure 1* by location. Targeted ablation resulted in CL prolongation and 33% AF conversion to SR or AT. No serious adverse outcomes related to System or Catheter were reported.

Conclusions: Identifying and targeting actual AF mechanisms for ablation using DD is feasible. Pre-ablation maps identified rotational, irregular reentrant, and focal activation patterns. Targeted ablation of mechanisms altered conduction and/or resulted in AF conversion. Long-term outcome data is needed.





***Above**: Anatomic location of identified mechanisms.*

***Top Right**: Dipole density map of PrAF — arrow represents focal firing adjacent to rotational activation.*

***Right**: Number of mechanisms and average fibrillatory CL by location.*

Site	# of Mech	Ave Fib CL (ms)
1	15	164 ± 32.9
2	14	169 ± 50.7
3	16	143 ± 14.2
4	29	165 ± 32.4
5	0	N/A
6	1	135
7	5	147 ± 25.0
8	17	169 ± 38.1
9	23	155 ± 40.2
10	17	171 ± 36.7
11	16	163 ± 37.3
12	14	187 ± 22.6

Electro-Functional Ablation Procedures: Initial Results from DDRAMATIC-SVT

HRS Abstract C - P005-71. *Heart Rhythm*, **Vol. 14, No. 5, May Supplement 2017. p S449**

Stephan Willems MD, PhD, Petr Neuzil MD, Andrew Grace MD, PhD, Richard Schilling MD, Mark CS Hall MD, Pier D Lambiase PhD, FRCP, Mattias Duytschaever MD, Alex Bittner MD, Atul Verma MD, FHRS, PhD. University Heart Center, Hamburg, Germany, Na Homolce Hospital, Prague, Czech Republic, Papworth Hospital, Cambridge, United Kingdom, Barts Health NHS Trust and QMUL, London, United Kingdom, Liverpool Heart and Chest Hospital, Liverpool, United Kingdom, Heart Hospital, London, United Kingdom, AZ Sint Jan, Brugge, Belgium, Pontificia Universidad Catolica de Chile, Santiago, Chile, Southlake Regional Health Centre, Newmarket, Ontario, Canada.

Background: Arrhythmias have been mapped by 3D, contact methods for the past 20 years. A new, non-contact, 3-D imaging/mapping system uses ultrasound (U/S) to acquire chamber anatomy and globally map localized dipole density (DD) charge-sources instead of the broader voltage-field.

Objectives: DDRAMATIC SVT was designed to demonstrate the safety and performance of the AcQMap System to create atrial DD maps in pts scheduled for ablation.

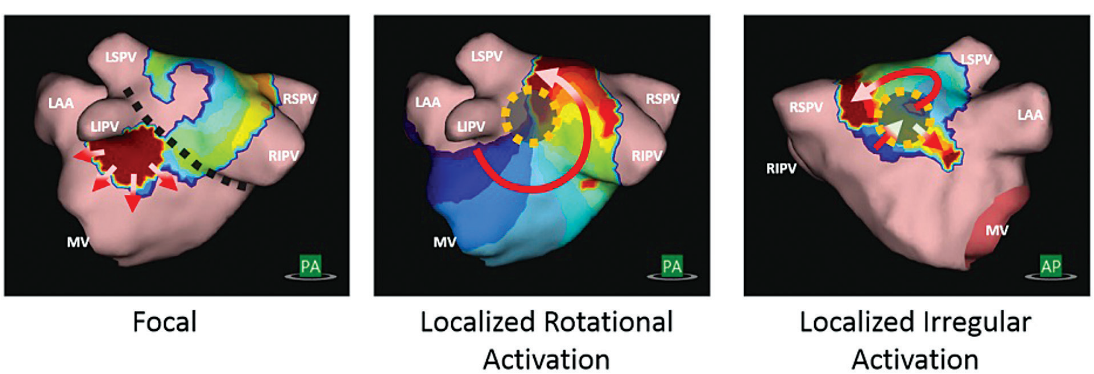
Methods: Pts were mapped using a catheter with 48 U/S transducers and 48 electrodes. U/S anatomies were acquired and 4 sec segments of SVT mapped. DD is inverse-calculated to subtract distant sources and globally display localized, raw activation data (no phase mapping) to highlight arrhythmic drivers and maintainers. *Figure 1.*

Results: A total of 84 pts were enrolled at 8 sites. (Mean age 59.8 yrs; 74% Male; 60% Atypical AFL 11%, AVNRT/AVRT 5%, PAF 17%, PersAF 67%; AF Duration 5.3 ± 5.1 yrs; LAD 45 ±5 mm) Pre-ablation maps delineating the mechanism(s) were created in 83/84 pts. Procedural SR was achieved via ablation or DCCV in 96.3% pts. Non-AF pts were followed to 7 days with no recurrence. Documented freedom from recurrence of treated or new arrhythmia in PAF was 83.3% (10/12) and 100% (8/8) and in PersAF was 81.8% (36/44) and 80% (20/25) at 3 and 6 months respectively. No system-related severe adverse events were reported.

Conclusions: AcQMap successfully created maps for characterization of multiple arrhythmias. In AF, use of AcQMap was able to help elucidate the underlying mechanism(s). A controlled clinical trial in PersAF patients is underway to validate these results.

AF Mechanisms

Conduction is displayed as retrospective moving color-map. Red is present location of leading-edge, while trailing color-bands represent past locations in time.



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New Insights into Persistent Atrial Fibrillation with the AcQMap® Dipole Density Mapping System

HRS Abstract C-PO02-68. *Heart Rhythm*, **Vol. 14, No. 5, May Supplement 2017. p S170 - S171.**

Arian Sultan, MD, Jakob Lüker, MD, Tobias Plenge, MD, Jan-Hendrik van den Bruck, MD, Susanne Erlhöfer, MD, Liz Kuffer, MD, Zeynep Arica, MD and Daniel Steven, MD. University Heart Center Cologne, Dept. of Electrophysiology, Cologne, Germany.

Background: The optimal treatment besides pulmonary vein isolation (PVI) in the setting of persistent atrial fibrillation (persAF) remains debatable. A coherent display and comprehension of persAF mechanism is still lacking. The newly introduced AcQMap® is a non-contact high-resolution system using a single array-shaped AcQMap® catheter (AC) providing 48 ultrasound probes and electrodes for 3D anatomy reconstruction and continuous dipole density (DD) mapping, displaying AFwave fronts or a voltage map.

Objective: We sought to evaluate and report our first findings for this new technology regarding behavior, distribution and reproducibility of displayed AF wave fronts.

Methods: First, a 3D anatomy was created and a DD AF map was recorded displaying AF wave fronts. Latter were discerned in 3 patterns: 1. Localized rotational, 2. Irregular mechanism, 3. Focal activation. After PVI using a Lasso® catheter a DD map was repeated to reveal activation changes after PVI. Then, identified target regions and pivot points were ablated. After thorough ablation of a target region DD re-mapping was performed. If AF did not terminate despite broad ablation an electrical cardioversion was performed.

Results: In 6 pts with persAF the AC delivered a reliable 3D anatomy. Post PVI, wave fronts with vicinity to PVs had vanished. Re-maps revealed predominant wave fronts sites: antero-septal LA, adjacent to LAA and at the postero-inferior LA. Thorough ablation at these breakthrough points reproducibly influenced or vanished wave fronts. In case of short ablation no influence on propagation front was detectable. Up to 5 DD re-maps were retrieved. In 3 (50%) out of 6 pts a specific termination of persAF was achieved, 2 pts directly into SR and 1 into mitral isthmus flutter, which terminated by a bidirectional block of the mitral isthmus line. The procedure and fluoroscopy time was 285±90 min. and 54±18 min. with a dosage of 18002±82239 cGycm2. No acute complications occurred.

Conclusion: The AcQMap® catheter and system delivers reproducible and reliable persAF mapping results and may facilitate identification of pivotal sites for persAF termination. Explicit ablation endpoints at these sites need to be specified. However, dipole density appears to shed further light in potential AF mechanism.[19]

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Does the Regional Incidence of Cycle Length of AF Mechanisms Differ between *de novo* and Redo Ablation Patients?

Europace **Abstract P292.** *Europace*, **Vol. 19, Supplement_3, 2017. p iii43.**

Atul Verma MD, Petr Neuzil MD, Andrew Grace MD, PhD, Richard Schilling MD, Mark CS Hall MD, Pier D Lambiase PhD, FRCP. Southlake Regional Health Centre, Newmarket, Ontario, Canada, Na Homolce Hospital, Prague, Czech Republic, Papworth Hospital, Cambridge, United Kingdom, Barts Health NHS Trust and QMUL, London, United Kingdom, Liverpool Heart and Chest Hospital, Liverpool, United Kingdom, Heart Hospital, London, United Kingdom.

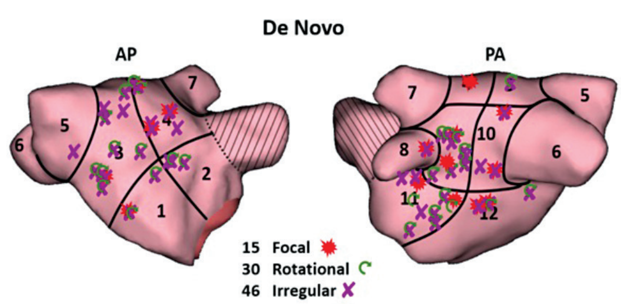
Background: AF pts can require >1 ablation to achieve successful outcome. The inability to map AF mechanisms (AFMs) may contribute to the lack of success. A new, non-contact, 3-D imaging/mapping system that uses ultrasound (U/S) to acquire chamber anatomy and dipole density (DD) instead of voltage to globally map AF, enabled characterization of AFMs in *de novo* and redo ablation pts.

Purpose: Quantify and compare regional incidence and avg. fibrillatory CL of AFMs in *de novo* and redo AF ablation pts.

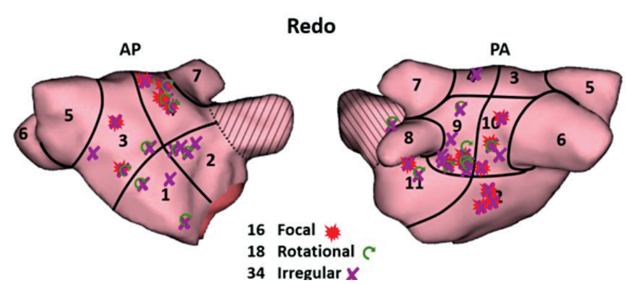
Methods: Pts were mapped prior to ablation using a 6-splined catheter with 48 U/S crystals and 48 electrodes. U/S LA anatomies were constructed and 4 sec of AF mapped. DD inverse solution subtracts distant sources and displays localized map of activation, highlighting arrhythmic drivers and maintainers. Conduction is displayed as a retrospective moving color-map. Red is present location of leading-edge, while trailing color-bands represent past locations in time. Identified AFMs were classified as focal, rotational and irregular.

Results: A total of 13 *de novo* and 10 redo pts were enrolled at 5 sites. *De novo*/Redo; 85%/75% Male, Age 58.2/62.9, AF duration 3.6 ± 5.6 /9.1 ± 4.9 yrs, LAD 42.3 ± 6.5/46.8 ± 6.5 mm, ablation conversion 15%/60%. AF duration and ablation conversion were significant (p = 0.01). Incidence of regional AFMs was not statistically different between the groups. All of the AFMs (100%) in the redo group were non-pulmonary vein (PV) related. Non-PV AFM incidence was similarly high in *de novo* (96.7%) (*Figure 1*). Regional and irregular AFM CLs in the redo group were significantly longer than the *de novo* group.

Conclusions: The incidence of regional AFMS is similar in *de novo* and redo pts with a similar proportion being non-PV related. AFM CL was longer in redo patients likely due to effect of prior ablation.



Site	# of Mech	Ave Fib CL (ms)
1	5	160
2	5	131
3	18	164
4	14	150
5	1	131
6	0	N/A
7	0	N/A
8	2	124
9	19	143
10	5	147
11	15	146
12	7	166



Site	# of Mech	Ave Fib CL (ms)
1	5	211
2	6	162
3	8	189
4	12	158
5	0	N/A
6	0	N/A
7	0	N/A
8	0	N/A
9	17	154
10	8	143
11	6	156
12	6	179

RESEARCH

Feasibility of Using an Intracardiac Mapping and Ultrasound Imaging Catheter to Estimate Left Atrial Volume

HRS Abstract C-PO02-73. ***Heart Rhythm*, Vol. 14, No. 5, May Supplement 2017. p S172-S173.**

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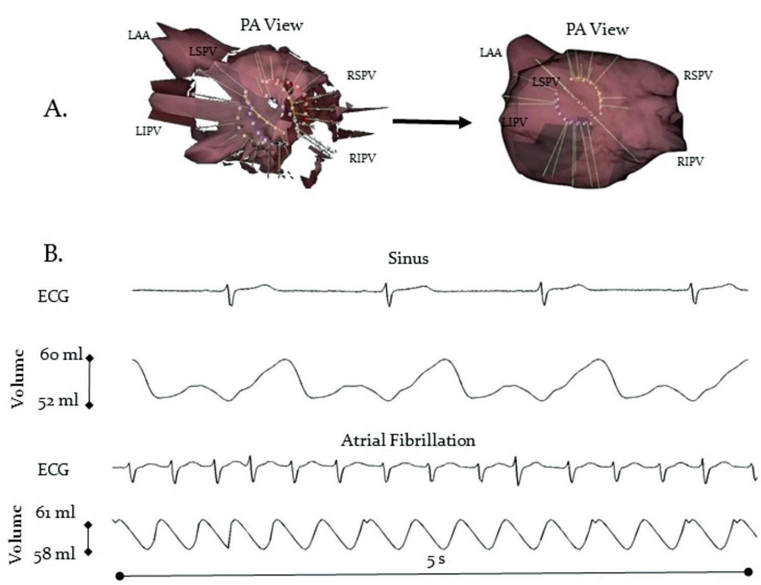
Background/Objective: Current echocardiography uses a planar, directional 2D array of ultrasound transducers (UT) to assess atrial mechanical function. This study shows first results of left atrial volume measurements using an omnidirectional 3D set of UT.

Methods: A new non-contact endocardial imaging and mapping system (AcQMap®) has been used to map atrial fibrillation (AF). Acquisition of the left atrial anatomy is based on 48 distance-ranging UT distributed across 6 catheter splines and interspersed with 48 electrodes for mapping cardiac activation. Separate anatomies were created in sinus rhythm and AF. Offline analysis of the anatomic data was used to reconstruct the full range of chamber wall motion throughout the cardiac cycle in sinus rhythm and AF to quantify left atrial volume.

Results: In sinus rhythm, the left atrial volume varies between 60-52 ml (Total LAEF=13.3%) and the functional phases of the cardiac cycle can be observed. During AF, the volume is between 61-58 ml (Total LAEF=4.9%) and depicts the more limited atrial function (Figure1).

Conclusions: The ultrasound imaging data collected by the AcQMap System enables a new method to quantify atrial contractile function. Analysis is underway to display simultaneous electrical activation with chamber contractility enabling the introduction of electro-functional procedures.



*LA anatomy reconstruction with ultrasound (**Panel A**)*
*LA volume during sinus rhythm and AF (**Panel B**)*

Phase Singularity Detection Applied to Dipole Density Mapping of Atrial Fibrillation

HRS Abstract B-PO04-073. ***Heart Rhythm*, Vol. 15, No. 5, May Supplement 2018, S419**

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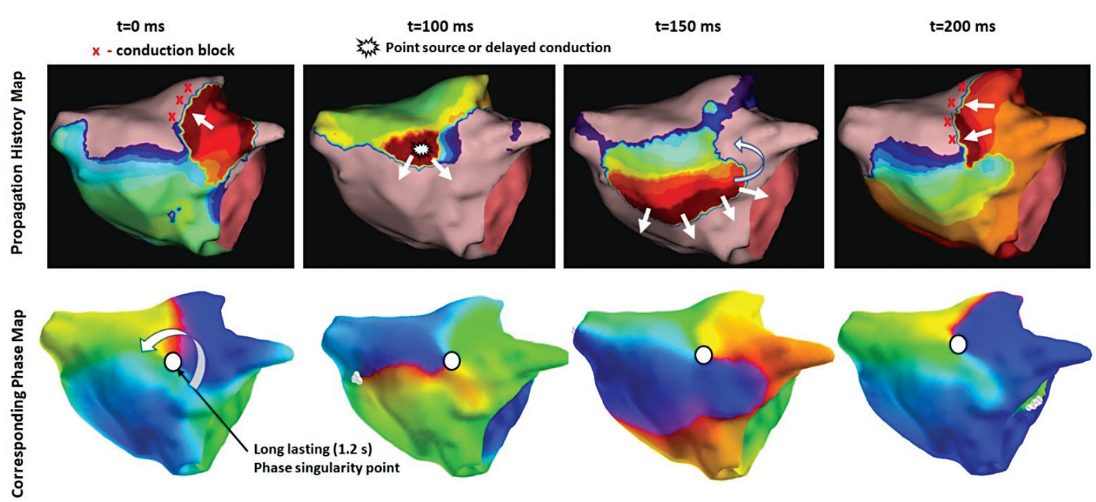
Background: Rotational activation may contribute to maintenance of atrial fibrillation (AF) and is challenging to detect. Activation data was acquired from a non-contact dipole density (DD) mapping system to assess rotation interpreted as phase singularity (PS).

Methods: Non-contact DD mapping (AcQMap, Acutus Medical, San Diego, CA) was performed in the left atrium of 12 patients undergoing catheter ablation of persistent AF. DD maps from two 4 s recordings were exported for each patient. Phase was calculated using custom software that employs sinusoidal recomposition and Hilbert transform. Phase lifespans longer than one cycle length and with relatively constant rotational velocity were counted as PS. Conduction patterns underlying regions with PS were assessed from voltage and DD maps.

Results: PS points were detected in all 24 recordings. Mean AF cycle length was 203±38 ms (range: 132 - 281). In total, 372 PS points were identified (15.5±7.6 PS points per recording). The mean PS lifespan was 305±153 ms, with the longest 1219 ms. When compared to underlying DD conduction patterns, identified PS locations were aligned with pivot-points of waves that rotated around or within localized zones of conduction delay, block, and/or collision.

Conclusions: PS can be calculated from DD measurements. Phase mapping based on sinusoidal recomposition demonstrates the presence of PS points related with both rotating waves and more complex conduction patterns. Further analysis is needed to verify if identified PS points denote mechanistically and clinically relevant areas of complex activity.



First-in-Man Biatrial Dipole Density Mapping of AT arising during Ablation of Persistent AF: An Iterative Strategy of Electrofunctional Mapping and Ablation

HRS Abstract C-PO03-70. *Heart Rhythm*, **Vol. 14, No. 5, May Supplement 2017. p S264.**

Rui Shi, MD, PhD, Eric Lim, MRCP, Wajid Hussain, MRCP, Karthik Viswanathan, MRCP, Lillian Mantziari, MD, PhD, Habib Khan, MRCP, Charlie Butcher, MRCP, Sandeep Panikker, MRCP, David G. Jones, MBBS, Vias Markides, FRCP and Tom Wong, FRCP. Royal Brompton and Harefield NHS Foundation Trust, Imperial College London, London, United Kingdom

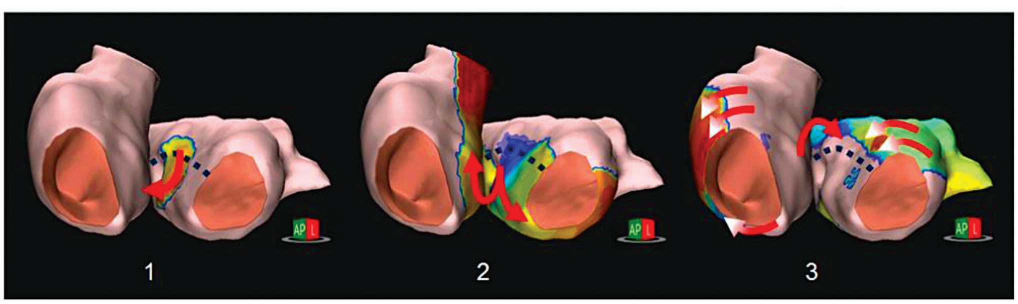
Background: Current methods of mapping AF are inefficient, low-resolution and cannot display in real-time. Consequently, AF ablation is rarely performed based on mapping.

Objective: Perform AF ablation using a novel mapping system to overcome these limitations.

Methods: A proprietary catheter to acquire CT/MRI quality chamber anatomy via intracardiac ultrasound was combined with real-time global, beat-to-beat noncontact dipole density (DD) mapping to locate therapeutic targets.

Results: A 73yr old man with PersAF underwent ablation under GA. PVI was initially performed. DD maps were generated from 30s recordings of LA activation followed by ablation of every identified zone of localized conduction exhibiting focal, rotational or irregular activation (hypothesized as functionally critical for driving or maintaining AF). Three zones were identified (mid anterior, mid posterior, posteroseptal LA). At each remapped stage of ablation, AF CL prolonged and organized into AT. LA activation did not encompass the full AT CL, so RA was mapped. Post-analysis revealed a figure-of-8 circuit encompassing both sides of the interatrial septum. Ablation was delivered at an isthmus site identified by DD map to successfully return the patient to sinus rhythm.

Conclusion: Electrofunctional DD mapping guided ablation of sites that may be critical for driving or maintaining AF. An iterative approach of remapping enabled breaking down AF complexity and organizing it into biatrial AT. This nascent technology may enable effective ablation of PersAF.



*Biatrial atypical flutter with figure-of-8 circuit spanning across the interatrial septum for one loop (**Panel 1**) and the mitral valve annulus for the other loop (**Panels 2** and **3**). Successful ablation lesion set indicated by dashed line.*

CASE STUDIES

Use of Novel Global Ultrasound Imaging and Continuous Dipole Density Mapping to Guide Ablation in Macro-Reentrant Tachycardias

HRS Abstract C-AB32-06. *Heart Rhythm*, **Vol. 14, No. 5, May Supplement 2017. p S80.**

Claire A. Martin, PhD, MRCP, Shohreh Honarbakhsh, MRCP, Ailsa McLean, DNP, NP, Richard J. Schilling, MD and Pier D. Lambiase, PhD, FRCP. Barts Heart Centre, London, United Kingdom

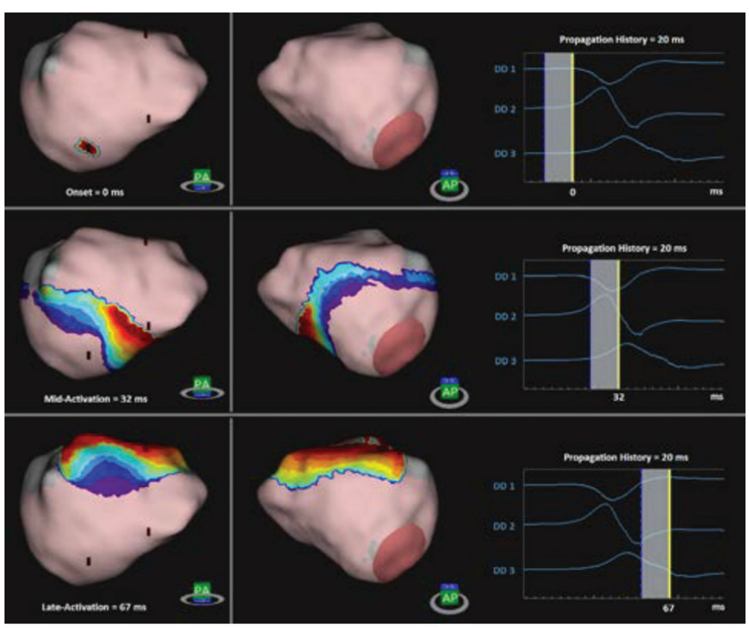
Background: The mechanism of persistent AF (PeAF) is not well defined and even when successfully ablated may evolve into atrial flutter (AFl). Sequential mapping is time consuming and complex.

Objective: We report the use of a novel non-contact ultrasound (US) imaging and mapping system (AcQMap) to characterize AFl.

Methods: The AcQMap is a basket catheter (48 US transducers, 48 electrodes) which acquires 100,000+ US points/min and 150,000 intracardiac unipolar voltage points/s. The 3D surface is reconstructed from the US point-set with mesh-density comparable to CT and electrical activation derived as 'dipole density' (DD) maps.

Results: Data were collected from 3 patients during first PeAF ablation (2 male, 48±13 yrs, time in PeAF 1.7±1.2 yrs). The AcQMap system demonstrated a macro-reentrant circuit in all and was used to guide ablation at the isthmus. Patient 1 presented in typical right AFl; Patient 2 presented in SR but with inducible AFl around the right upper pulmonary vein; Patient 3 presented in AF which organised to an AFl around the posterior wall, and after ablation and termination of this, to a typical right AFl. The figure shows an isochronal plot of the initial AFl activation sequence from Patient 3, with breakout at the inferior aspect of the LA posterior wall. All AFl terminated during ablation. Validation was by contact mapping, with bidirectional block as the procedural endpoint.

Conclusion: Real-time US and DD based mapping using the AcQMap provides high resolution electroanatomical maps, allowing rapid & accurate targeting of critical isthmuses for ablation. This technique also raises the possibility of mapping AF more precisely to identify potential ablation targets.



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