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CLINICAL RESEARCH

An initial experience of high-density mapping-guided ablation in a cohort of patients with adult congenital heart disease

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Aims In the management of both ventricular and supraventricular tachycardia in patients with congenital heart disease (CHD) catheter ablation has now been recognized as one of the mainstays.

Methods and results We review our initial experience of using the Rhythmia mapping system in a cohort of 12 adult CHD patients presenting with multiple arrhythmia substrates. A total of 78 arrhythmia maps were attempted in a total of 15 procedures, but possible due to the dilatation of the target chamber only 44% of maps were able to reconstruct the entire arrhythmia. All patients underwent pre-procedure 3D imaging (either cardiac magnetic resonance or computed tomography), but image integration was suboptimal. A median of two maps per patient were finally analysed and acquisition took in median 22 min with a median number of 12 574 (8230–18 167) mapping points. Procedural data with a total duration amounting to in median 285 (194–403) min, with a median total fluoroscopy exposure of 7.5 (5.2–10.7) min. After a median of 1.5 procedures [median of 12 (8–16 months)], nine patients remained in stable sinus rhythm or atrial paced rhythm, while three patients had further sustained recurrences. One of these passed away in end-staged heart failure.

Conclusion This initial experience of using high-density mapping for arrhythmia management in patients with CHD allowed rapid acquisition of multiple maps with high accuracy to identify surgical scars and fibrosis, however, it was limited by large atrial volumes and a high percentage of incomplete maps resulting in modest clinical success.

Keywords Catheter ablation • Multielectrode mapping • Congenital heart disease • Arrhythmias

Introduction

In the management of both ventricular and supraventricular tachycardia in patients with congenital heart disease (CHD) catheter ablation has now been recognized as one of the mainstays.[1–6] The majority of arrhythmia substrates in CHD patients is re-entrant in nature and frequently caused by the preceding surgical interventions, which result in scar tissue (e.g. atriotomy scars) that can create protected channels of conduction that can serve as critical isthmuses in re-entrant circuit tachycardia.[7–9] This was also convincingly demonstrated for the most frequent CHD Tetralogy of Fallot (ToF) with scar-defined re-entrant circuits that serve as the substrate for sustained ventricular tachycardia (VT).[10] However, also patients with non-palliated CHD can suffer from sustained arrhythmias, mostly caused by significant chamber dilatation. The success of atrial tachycardia (AT) ablation in CHD is largely influenced by the underlying cardiac anatomy and surgical repair, along with the current haemodynamic sequelae of the anatomy and repairs.

We review our initial experience of using the Rhythmia mapping system to a cohort of adult CHD patients presenting with arrhythmias in a single centre.

Methods

Patients with CHD and sustained arrhythmia were studied using the Rhythmia mapping system (Boston Scientific) from November 2015 to

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What's new?

- First experience of high-density mapping in a cohort of complex patients with congenital heart disease.
- Rapid multi-electrode mapping of multiple arrhythmias.
- High-resolution depiction of scars after previous surgical and ablation intervention.

March 2018 at the Royal Brompton and Harefield NHS Foundation Trust. Patients were selected to be studied using the Rhythmia system if they were listed on the waiting list for ablation CHD and had no access obstruction that would necessitate remote magnetic navigation.

Pre-procedural preparation

All patients underwent careful and comprehensive assessment of their haemodynamic condition including transthoracic echocardiography (TTE) and 3D imaging. Surgical notes were reviewed whenever available to identify surgical scars from various surgical interventions. All arrhythmia documentations were reviewed to identify the dominant arrhythmia and possible additional arrhythmia substrates including atrial fibrillation (AF).

3D imaging for road mapping

In order to understand the individual 3D anatomy, 3D DICOM datasets were reviewed and reconstructed to allow the investigators to familiarize themselves with the case ahead of the invasive procedure. Imaging DICOM datasets were either contrast cardiac computed tomographies or non-contrast cardiac magnetic resonance images (CMR). Scans were reconstructed on the Rhythmia HDx DM mapping software and merged with the 3D chamber of interest (*Figure 1*).

Invasive catheter procedure

All patients were studied in a fasted state and after informed written consent had been obtained, under assisted sedation or general anaesthesia applied by a cardiac anaesthetist with continuous invasive arterial pressure and careful fluid monitoring. Decapolar catheters (Parahis, BARD) were positioned in the coronary sinus (CS) and/or in the free wall of the right atrium (RA) to serve as timing references for the high-density mapping. The 64-pole basket mapping catheter (IntellaMap Orion; Boston Scientific), which incorporates small unidirectional electrodes (0.4 mm^2; 2.5 mm spacing) was advanced into the RA using a steerable sheath (Agilis, St Jude Medical, medium or large curve) in all but the first patient (where only a short sheath was used). In case of suspicion of a left atrium (LA) origin, a double trans-septal puncture was performed after transoesophageal echocardiography excluded an LA thrombus or via an ASD if present. Using a double trans-septal access allowed to have both the ORION and the ablation catheter in the LA without the need for exchange (which could have increased the risk of e.g. air embolism). A bidirectional mapping and ablation catheter (IntellaNav, Boston Scientific) was used in all cases.

We studied all patients on continued oral anticoagulation and vascular access was gained using ultrasound guidance. After vascular access was gained, Heparin was applied in bolus IV applications with a target activated clotting time (ACT) of 300–350 s. The ACT was tested every 30 min and further Heparin was applied if necessary.

Acquisition of the sequential high-density map

Bipolar electrograms were automatically collected during stable rhythm using the following beat acceptance criteria: (i) cycle length stability, (ii) propagation DR [difference in time in activation between two electrodes of the reference catheter (mostly decapolar catheter in CS or RA free wall)], (iii) respiration phase allowing data acquisition at a constant respiratory phase, and (iv) catheter stability. Maps and intracardiac signals were acquired predominantly through the Orion, but additional mapping was added if necessary using the ablation catheter.

Ablation settings and endpoints

After the critical isthmus or focal origin was identified, irrigated tip radiofrequency (RF) ablation was applied using 30–45 W with a flow-rate of 17 ml/min for up to 120 s and a maximum temperature of 43°C. If a linear lesion was required, the catheter was dragged along the intended ablation line once local signal abatement was achieved. At sites of arrhythmia termination, a bonus RF application was applied to assure that the final blocking lesion was transmural and long lasting. For every linear lesion deployment, the criterion of bidirectional block was attempted by pacing from both sides of the intended line.[11–14] To test for other arrhythmias, further burst pacing was performed for up to 10 s with decreasing cycle length (CL) until atrial refractoriness or 200 ms CL was reached. At least four different sites in the right and left atrium (via the CS catheter) were tested and subsequently inducible ATs were mapped and ablated. In case of AF induction, direct current cardioversion (DCCV) was performed. If deemed clinically indicated, pulmonary vein isolation was performed using the Rhythmia system as described previously.[15,16] At the end of the procedure, all catheters and sheaths were removed, and the patient was carefully monitored in the recovery or high-dependency unit.

Follow-up

Patients were followed for clinical and asymptomatic recurrences by a team of electrophysiologists and CHD specialists with regular clinic visits. Holter recordings and a 12 lead electrocardiograms (ECGs) were assessed every 6 months. Monitoring from implanted devices was also regularly reviewed. Any recurring symptoms prompted immediate review and documentation of further arrhythmias was carried out. Any sustained AT was considered for repeat ablation procedure.

Statistical analysis

Continuous variables are expressed as mean ± standard deviation, or median values with 1st and 3rd quartiles in case of non-normal distribution. If clinically relevant, minimum and maximum values are also indicated. Comparisons were assessed using the Wilcoxon test for unpaired data and a *P*-value of <0.05 was deemed significant.

Results

3D map acquisition

A total of 15 procedures were carried out in 12 patients (7 female, mean age 49 ± 10.3 years) with a total of 78 attempted arrhythmia maps (*Table 1*). Underlying CHD condition consisted of patients with moderate CHD complexity in eight and great CHD complexity in four patients, ranging from sinus venous ASD (3 patients), Ebstein's anomaly (2 patients) to double outlet right ventricle (DORV, 2 patients), and mitral (1 patient) or tricuspid atresia (1 patient) (ref. *Table 2*). Nine out of 12 patients had undergone previous ablation

procedures using 3D electroanatomical mapping (CARTO) in all cases with a single mapping and ablation electrode. Five patients had previously undergone device implantation with a dual chamber pacemaker in four and an implantable cardioverter-defibrillator in 1 patient.

Arrhythmia substrates

Besides one patient with ToF and frequent ventricular ectopy (VE) after RV VT ablation, all other patients presented with atrial arrhythmias. In one patient with Ebstein's anomaly and surgical repair of the tricuspid annulus, 'pseudo regular' AF was confirmed only by intracardiac mapping, while in further two patients AT degenerated into AF at some point during the index map (one large RA in Ebstein's anomaly and one with common atrium). Due the atrial distension and excessive scaring, the P wave morphology during AF may impose as monomorphic and occasionally pseudo regular with close to fixed PP intervals. Intracardiac mapping however revealed irregular and chaotic activation with the area that dominates the P wave being in a bystander area. Eight patients were mapped in sustained AT with four index maps of the LA, three of the RA, and one for both RA and LA.

All patients presented with markedly dilated atria with a median 3D volume mapped using the ORION catheter of 199 mL (146–251 mL). However, in 7/15 procedures, the acquired 3D map was clearly smaller than the 3D reconstructed chamber anatomy (*Figure 1*). There was no difference between source data from CMR ($n = 8$) or CT ($n = 7$).

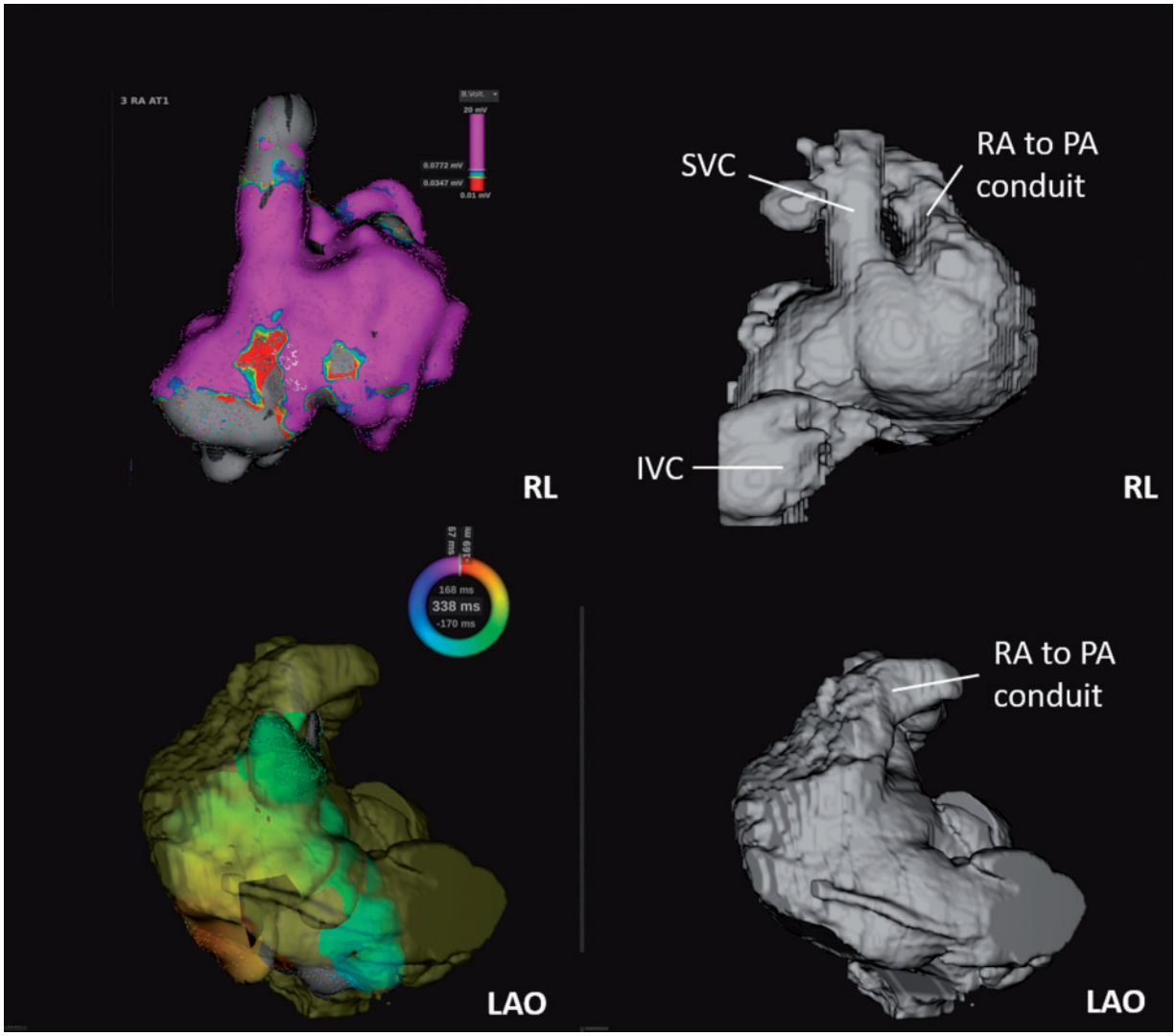

Figure 1 Example of a 3D reconstruction from cardiac magnetic resonance imaging of a patient with tricuspid atresia and modified RA to PA Fontan palliation. Right panel demonstrates reconstructions of 3D DICOM datasets to illustrate the underlying anatomy in RL and LAO projection. The left upper panel shows the electroanatomical mapping information and the left lower shows the same map superimposed on the 3D scan to illustrate the incomplete map. IVC, inferior caval vein; LAO, left anterior oblique; PA, pulmonary artery; RA, right atrium; RL, right lateral; SVC, superior caval vein.

The median CL of the mapped ATs was 345 ms (270–453 ms) with predominant 2:1 atrioventricular (AV) nodal conduction. Unfortunately, only 34/78 (44%) of maps attempted were deemed to be complete as arrhythmias were either non-sustained and terminated into sinus rhythm [(SR) 19, 24%; with mechanical termination in 9, 12%], degenerated into a different tachycardia (20, 24.5%), or into AF (5, 6%). Finally, a median number of two maps per patients were completed and analysed subsequently. Mapping time for these maps took in median 22 min with a median number of 12 574 (8230–18 167) mapping points. Index maps were typically covering the entire AT-CL when dealing with a re-entrant AT. Re-entrant mechanism was the most common AT substrate with previous atriotomy scars being the most frequently observed substrate. Cavotricuspid isthmus dependent arrhythmias were present in 4/15 procedures (*Figure 2*). We mostly observed re-entrant tachycardia but localized re-entry was also observed typically after previous ablation and/or at sites of cannulation scars (*Figure 3*).

The only patient with ventricular arrhythmia in our cohort presented with frequent monomorphic VE. The initial right ventricular (RV) map demonstrated the typical RV outflow tract patch scar and the result of a previously deployed ablation from the pulmonary valve to the tricuspid annulus (*Figure 4*). The ectopy was subsequently localized in the left ventricle close to the left ventricular (LV) summit area[17] and was mapped using the ablation catheter.

Table 1 Baseline characteristics

Patients, *n*	12
Female, *n* (%)	7 (63.6)
Age at ablation procedure (years), mean ± SD	49 ± 10.3
Previous ablations, *n* (%)	12/15 (80)
Systemic ventricular systolic function, *n* (%)	Normal, 8/12 (66.6) Mildly impaired, 2/12 (18.2) Moderately impaired, 2/12 (25)
CHD complexity score, *n*	Moderate complexity, 8/12 Great complexity, 4/12
Previous surgeries, median (IQR)	2 (1.5–2.5)
Age at first surgery (years), median (IQR)	6 (1–22)
Time surgery to first arrhythmia (years), median (IQR)	16 (2–25)
Previous device implantation, *n* (%)	PM, 4/12 (33.3) ICD, 1/12 (8.3)

Scar identification by voltage mapping

Using an initial bipolar cut-off of 0.3 mV and 0.05 mVs all maps were assessed in order to identify the previously created surgical scars and any further acquired fibrosis. This can be individualized further depending on the noise level of the local electrograms in an area of interest. The median scar area identified ranged from none to 50 cm^2. *Figure 5* illustrates the impact of different confidence levels to eliminate the low voltage area from the automatic analysis in a patient with common atrium.

Table 2 Description of congenital condition(s) and corresponding surgical procedures

Congenital conditions	Surgical procedure	Surgical scars
Ebstein's anomaly	Bidirectional Glenn, TVR	Right atriotomy, by-pass cannulation
DORV, VSD, PS	Rastelli procedure, RV to PA conduit and re-do	Right ventriculotomy, by-pass cannulation, VSD closure patch, valved homograft conduit
MA, DORV, PS and sub-PS, non-restrictive VSD, bilateral SVCs	Atrial septostomy, open PV valvotomy, PA banding	Atriotomy, RVOT, by-pass cannulation
TOF	TOF repair (open valvotomy, pericardial patch to RVOT and Dacron patch to VSD) PVR	RVOT patch and VSD closure patch, by-pass cannulation
TA, non-restrictive-VSD, bilateral SVCs, aberrant origin of left subclavian artery from aorta	Modified Fontan	Right atriotomy, by-pass cannulation, suture RAA to PA
Hypoplastic RV, ASD, VSD, PA, hypoplastic PA	Waterston shunt	(Extra-pericardial), by-pass cannulation
CoA, BAV, sub-AS	Konno procedure, AVR, CoA repair	Aortic root and LVOT, RVOT, by-pass cannulation
Complete Atrioventricular septal defect (AVSD with common atrium)	AVSD repair, LAVV repair followed by replacement	By-pass cannulation, left atriotomy
ASD, BAV	Surgical ASD closure, AVR	By-pass cannulation, right atriotomy, aortic root
ALCAPA	Takeuchi procedure	By-pass cannulation, aorta and PA
Ebstein's anomaly, PFO	Bidirectional Glenn, PFO closure, TVR	Right atriotomy, by-pass cannulation
Fenestrated sinus venosus ASD with left to right shunt	None	None

ASD, atrioseptal defect; AVSD, atrioventricular septal defect; BAV, bicuspid aortic valve; CoA, Coarctation of the Aorta; IVC, inferior caval vein; LAVV, left atrioventricular valve; LVOT, left ventricular outflow tract; PFO, persistent foramen ovale; RA, right atrium; RV, right ventricular; RVOT, right ventricular outflow tract; SVC, superior caval vein; TOF, Tetralogy of Fallot; VSD, ventricular septal defect.

In the 34 complete maps, a total of 30 critical targets were identified and subsequently successfully ablated using a median RF delivery duration of 39 (29–58.1) min. In the remaining four maps, no clear ablation target was identified, and RF ablation did not terminate the arrhythmia. Non-inducibility was achieved in 9/15 procedures and atrial fibrillation was induced as the last atrial arrhythmia in three cases. Finally, DCCV was performed in a total of four cases. Typically, the CL of the subsequently inducible arrhythmias was shorter than the index AT. Localized re-entry was typically seen only secondary to an initial re-entrant AT.

Table 3 summarizes the procedural data with a total duration amounting to in median 285 (194–403) min, with a median total fluoroscopy exposure of 7.5 (5.2–10.7) min, and 408.5 (195–1196) μGym^2 dose area product.[18]

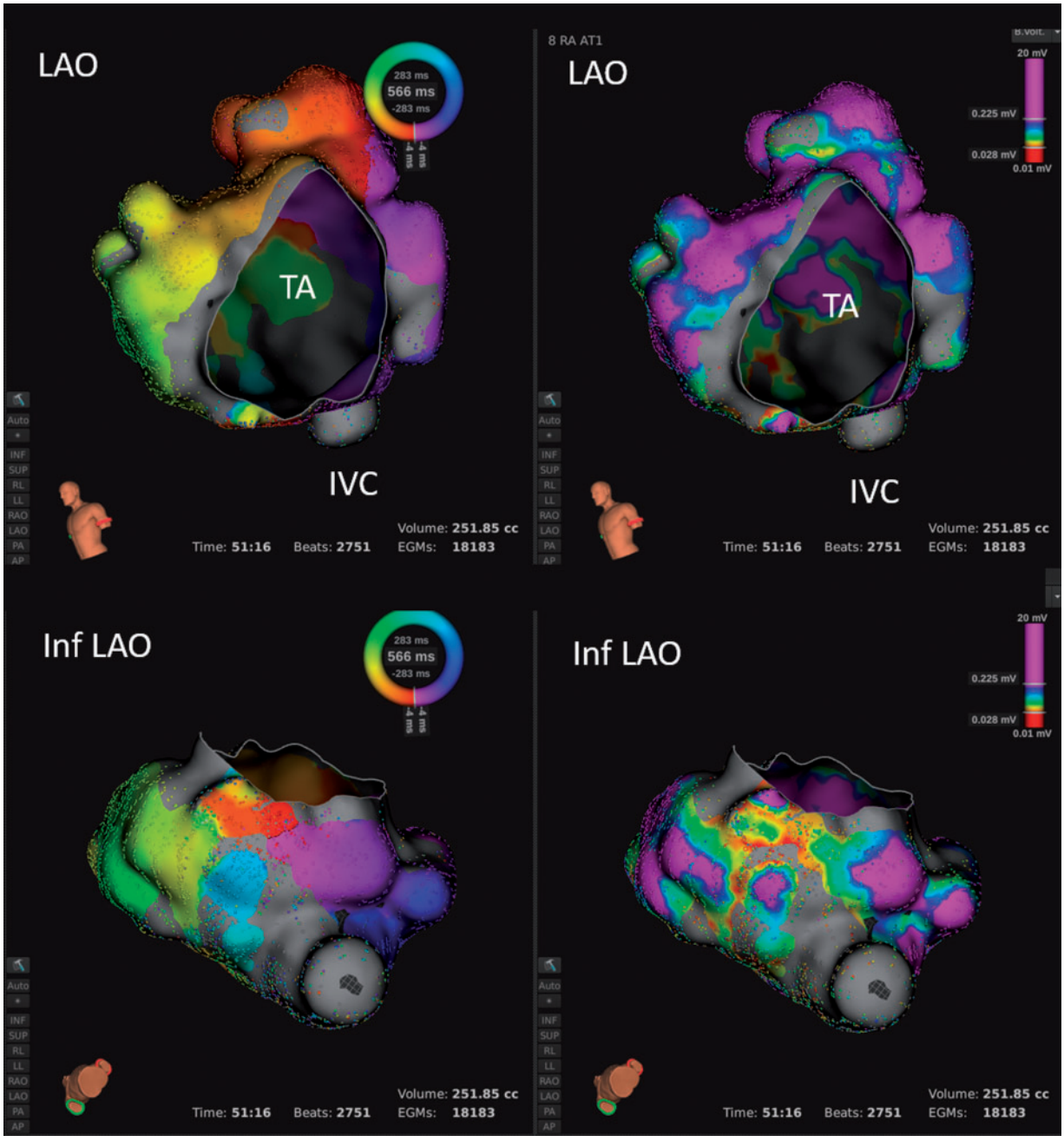

Figure 2 Example of cavotricuspid isthmus re-entry in a patient with previous ablation and common atrium (mitral atresia). Clockwise activation around the TA was confirmed and ablation terminated the slow re-entry into SR. Left panels show the local activation information, while the right panels demonstrate voltage amplitude information. IVC, inferior caval vein; LAO, left anterior oblique; TA, tricuspid annulus.

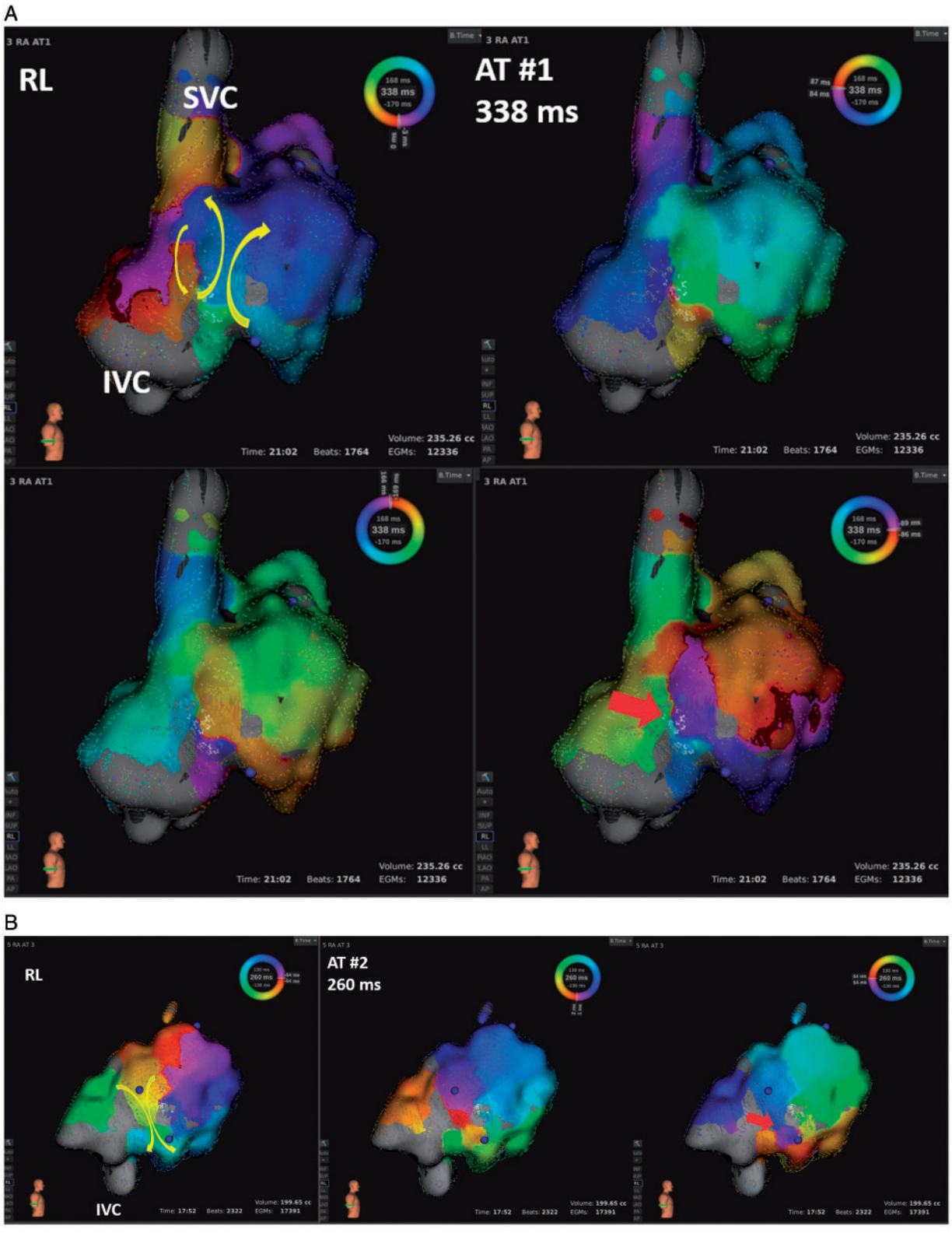

Figure 3 Multiple tachycardias in a single patient (same as in *Figure 1*) to depict various scar-related substrates. (*A*) Activation map of AT#1 with 338 ms CL showing a figure of eight re-entry with a small isthmus (red arrow). RF at this site terminated the AT into SR. (*B*) Burst pacing in the same patient induced AT#2 with a CL of 260 ms, which is remapped (please note the missing SVC). Now the figure of eight re-entry mechanism is travelling through the corridor between the two scars and ablation again terminated at the red arrow. (*C*) Further burst pacing induced AT #3 with 240 ms CL. Remap of the RA demonstrates a localized re-entry around a small central scar area more posterior than the previous scar areas (oblique posterior anterior PA projection). Again termination at the red arrow. AT, atrial tachycardia; CL, cycle length; IVC, inferior caval vein; PA, pulmonary artery; RA, right atrium; RF, radiofrequency; RL, right lateral; SR, sinus rhythm; SVC, superior caval vein.

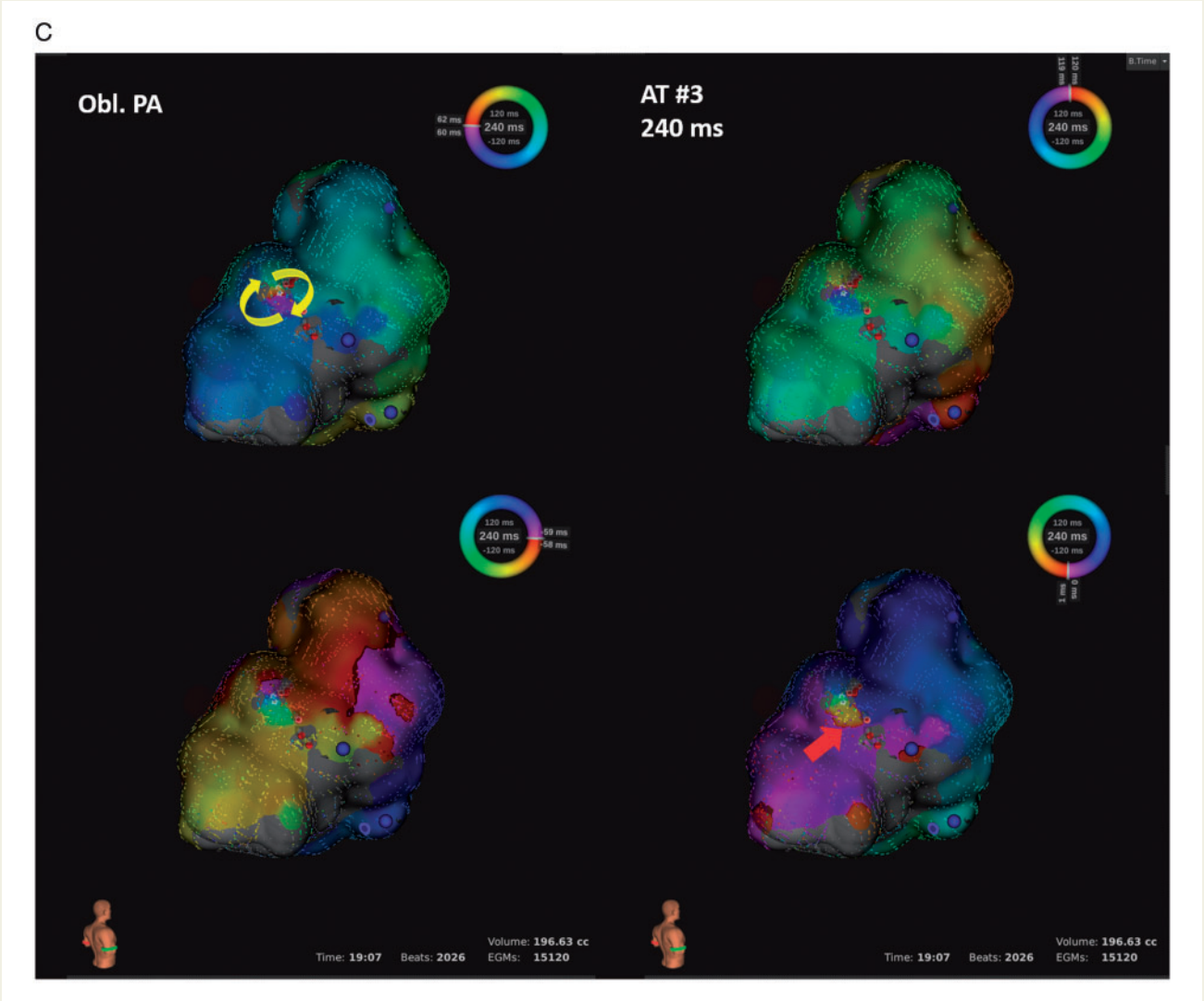

Figure 3 Continued.

Follow-up results

After the procedures all patients underwent immediate follow-up investigations which ruled out any acute complication or damage to intracardiac structures out by TTE. During a median follow-up of 12 (8–16) months, eight patients suffered from recurrent arrhythmia (66%) necessitating further invasive ablation procedures in six of them. Repeat ablation was carried out with either the Rhythmia mapping ($n = 3$) or the CARTO mapping system ($n = 3$). After a median of 1.5 procedures [median follow-up duration of 12 (8–16) months)], nine patients remained in stable SR or atrial paced rhythm, while the remaining three patients experienced further sustained arrhythmia. Antiarrhythmic medication was continued with beta-blockers in eight patients and/or Amiodarone in five patients.

One patient died 8 days after a second Rhythmia-guided AT ablation in end-stage heart failure and after initially achieving SR by RF delivery. During the short-time follow-up, this 44 years old patient had further sustained AF despite being continued on amiodarone. In the presence of a hypoplastic left ventricle with double outlet right ventricle (DORV) the right-sided AV valve was severely regurgitant but was deemed inoperable.

Predictors of success/failure

Due to the inhomogeneous cohort and the various underlying surgical settings, we were unable in this small sample size to identify factors for success or failure. Interestingly, the volume of the atrial chambers mapped or the complete vs. incomplete merge with the 3D image reconstruction did not seem to predict a more difficult procedure.

Complications

We observed no acute or late complications in any of the patients. Specifically, we did not observe any damage to valvular structures or thrombo-embolic events.

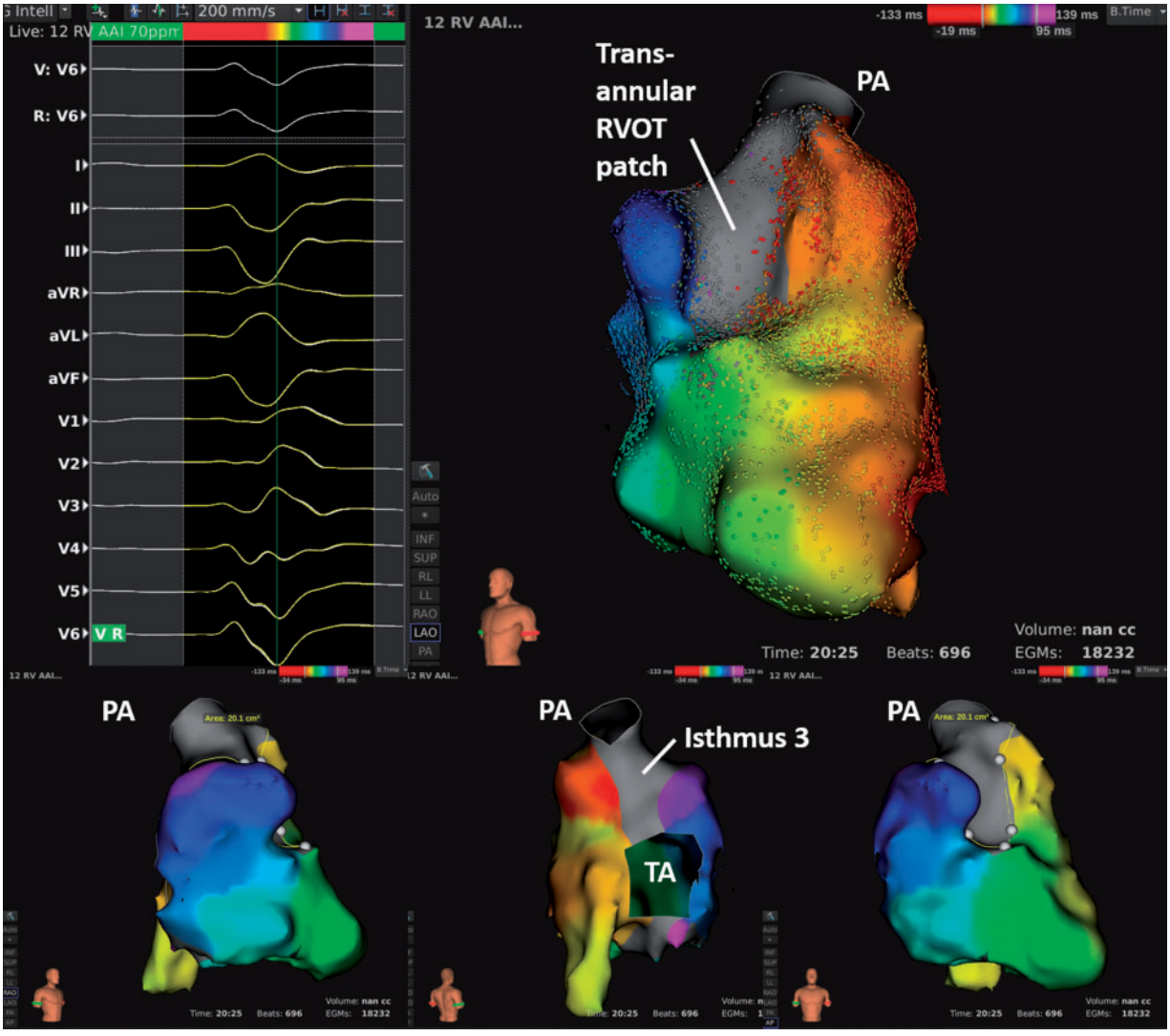

Figure 4 RV map in a patient with Tetralogy of Fallot in permanent atrial pacing. The left upper panel shows the SR with the typical right bundle branch block like QRS complex. Please note the colour range above the ECGs that is reproduced on the right upper panel as well. The outflow tract patch is transannular, and therefore, there is no Isthmus 1 (surgically created between the outflow tract patch and the pulmonary valve) and the patch area is 20.1 cm^2. Isthmus 3 (surgically created isthmus between the ventricular septum patch and the pulmonary valve) is also blocked as this patient had undergone previous VT ablation and presented now with LV ectopy. The lower three panels demonstrated three projections from RAO, oblique PA, and PA, respectively. ECG, electrocardiogram; LV, left ventricular; RAO, right anterior oblique; RV, right ventricular; SR, sinus rhythm; VT, ventricular tachycardia.

Discussion

We report on our initial experience of using the Rhythmia mapping system in a highly selected cohort of CHD patients with re-entrant or focal arrhythmia. Despite initial successful ablation, we observed a relatively high recurrence rate of 66% after the index ablation using the high-density mapping system. Clinical success after repeat ablations was achieved finally in 75% of patients during a median of 12 months follow-up period, mostly on continued anti-arrhythmic medication. This outcome is comparable to other 3D mapping systems in similar settings and demonstrates that the optimal ablation strategy for this challenging patient cohort is not necessarily depending on the 3D mapping system.[4,5,19] The specific challenges included the complete sequential acquisition of the entire target chamber, access to all regions including areas 'behind' structures such as Eustachian ridge, deployment of complete ablation lesions, and finally multiple substrates.

Advantages of multielectrode high-density mapping for CHD substrates

As reported by a number of groups previously, the major advantage of the Rhythmia system is the fast acquisition of multiple mapping points with the mini-basket and its' small electrodes.[20–23] This allows

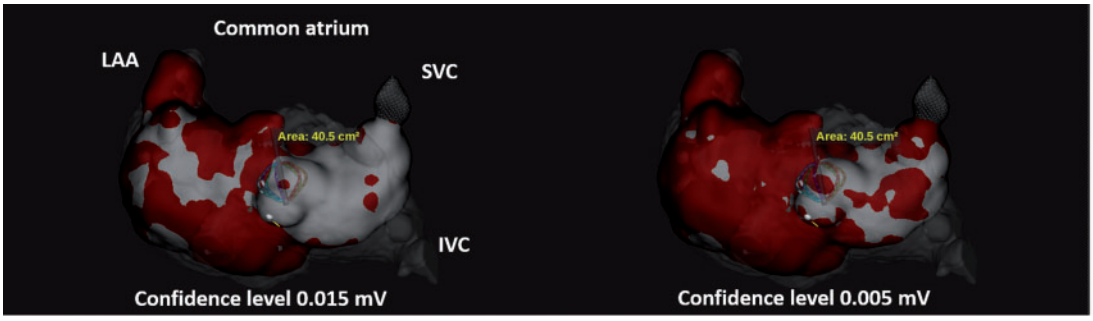

Figure 5 Example of different confidence levels (left: 0.015 mV, right: 0.005 mV), which excludes scar areas from the automatic analysis in a patient with common atrium. Please note that with the higher setting, nearly the entire RA area is depicted as scar making bystander activation most likely. This setting however needs to be individually adjusted and depends on the signal to noise ratio (ref Latcu *et al.*[22]). IVC, inferior caval vein; LAA, left atrial appendage; RA, right atrium; SVC, superior caval vein.

Table 3 Procedural data

Ablation procedures, total	15
Oral anticoagulation, *n* (%)	Warfarin, 12/15 (80%)
	NOAC, 2/15 (13.3%)
INR pre-procedure, median (IQR)	2.5 (1.9–2.7)
Baseline ECG, *n* (%)	SR, 2/15 (13.3)
	Paced, 4/15 (26.6)
	AT, 7/15 (46.6)
	AF, 2/15 (13.3)
GA, *n* (%)	12/15 (80)
Intra-procedural TOE, *n* (%)	7/15 (46.6)
Procedure time (min), median (IQR)	285 (194–403)
Fluoroscopic time, (min) median (IQR)	7.5 (5.2–10.7)
DAP (cGym^2), median (IQR)	408.5 (195–1196)

AF, atrial fibrillation; AT, atrial tachycardia; DAP, dose area product; ECG, electrocardiogram; IQR, interquartile range, SR, sinus rhythm; TOE, transoesophageal echocardiography.

depiction of scars and low voltage areas that surpass large electrode sequential mapping resolution. Especially for previously ablated areas, surgical scars, and atrial fibrosis due to chamber dilatation, this information is very valuable. Being able to 'pre-set' the confidence level allows adjusting the 'field of view'. In addition, using the rowing electrode to identify local conduction in detail is equally important in the post-processing phase. Detailed analysis is needed however to understand and interpret the acquired maps.

Disadvantage of multielectrode mapping system in its' current version

As with all novel tools, the operators needed to overcome a learning curve to get familiar with this mapping system. Especially the steerability of the mini-basket and the lack of direction indicators made the 3D mapping process challenging. Possibly, this resulted in the large amount of terminations/changes of arrhythmia in our cohort. Especially in very enlarged and abnormally formed chambers, the differentiation between scar and non-contact is difficult to make and may result in non-mapped areas. The need for a stable arrhythmia that lasts long enough to be completely mapped is an obvious further limitation for any sequential mapping system. With regard to this, the only system capable of overcoming this limitation at present is the non-invasive multielectrode mapping system ecVUE (CardioInsight),[24] which has been however limited by the 'blind spot' of septal activation with surrogate right and left atrial break-out activation.[25] Multiple maps were acquired in a very short acquisition time, but the experience in CHD patients is still limited so far.

Incomplete 3D image integration

The use of 3D image integration is a standard during CHD ablation procedures using various 3D mapping systems. The 3D roadmap helps to ascertain that all parts of a given target chamber have been mapped, such that critical isthmuses cannot be overlooked by not having mapped a given region. This is of great importance in grossly enlarged chambers. One of the established 'tricks' is to map e.g. the aortic arch to allow 'merging' of the 3D scan over this essentially non-moving structure. However, the Rhythmia system in its' current version does not allow to move all 3D reconstructions in a 'linked' fashion but moves each chamber independently. The only alternative is to merge each target chamber separately, therefore the roadmap 'guidance' nature of the pre-acquired scans is somewhat diminished. In our cohort, this resulted in incompletely merged maps in nearly half of the procedures. An incomplete map may miss a critical part of a given arrhythmia, while the 'registered' roadmap may also help to avoid pushing the mini-basket to aggressively against the myocardium, thereby avoiding mechanical ectopy and in the worst-case termination or changing the arrhythmia.

Accessibility of target chambers is another well recognized problem in CHD patients. Due to our experience with remote magnetic navigation we elected not to use the Rhythmia mapping system in patients with atrial switch for transposition of the great arteries (TGA, such as Mustard or Senning operation) or total cavo pulmonary connections (TCPC).[5] This would have required transbaffle access, resulting possibly in a higher resolution of the acquired mapping information, but most likely resulting in substantially higher radiation

exposure and procedure times. Theoretically, the ORION catheter could be advanced also in a retrograde fashion across the aortic and subsequent AV valve, but again most likely on the expense of radiation and procedure duration.[21]

Atrial fibrillation as an important clinical arrhythmia

Catheter ablation of sustained AT is an established ablation strategy which is greatly facilitated using high-density 3D mapping as shown in our experience. However, a subset of our patients also presented with sustained AF which occasionally looked pseudo-regular on the surface ECG. This is a growing clinical problem in the CHD population as patients survive longer and present with larger atrial chambers.[26]

Future outlook for high-density multielectrode mapping in congenital heart disease patients

This is our very initial experience using the Rhythmia mapping system in CHD patients, and it is obviously not yet a fully evolved strategy. Having struggled much with changing arrhythmias and multiple substrates, we would propose a different approach: In a first attempt, a complete map of the target chamber in stable sinus or paced rhythm could identify all conduction barriers (previous surgical scars or previous ablation lines). This should be followed by 'closure' of potential conduction gaps through obvious pathways such as the cavotricuspid isthmus, corridors between atriotomy scars, and Crista terminalis or the AV annulus and finally from cannulation scars to the inferior or superior caval veins. These ablations should be carried out with the best possible prediction of complete trans-murality (e.g. contact force), which is currently not available for this mapping system. As CHD patients may present with much thicker myocardium even in the atria, direct visualization may even be needed to achieve durable transmural lesions. Once all ablation targets have been completed during stable rhythm, pacing attempts should be made to identify additional sustained arrhythmias. Focussed mapping in the region of interest alone during short lasting arrhythmia, as demonstrated elegantly by the Bordeaux group in two cases,[27,28] could potentially avoid mapping the entire and most likely grossly dilated chamber. A multicentre approach is therefore proposed to acquire enough data for the various CHD conditions to make firm recommendations.

In summary, high resolution mapping is definitely helpful when addressing the complex cohort of CHD patients. However, the system needs to undergo substantial improvements with regards to image integration and especially implementation of contact force measurements to assure best lesion deployment.

Limitations

This is a retrospective analysis of the use of the Rhythmia mapping system in a highly selected patient cohort with complex CHD conditions that mostly had failed previous ablation attempts. Moreover, the cohort itself is very heterogeneous and especially the size of the target chamber made complete mapping a substantial challenge. The operators' learning curve with both the manipulation of the mini-basket catheter and the map settings need to be taken into consideration when judging the outcome of these ablations, aiming at mapping sustained arrhythmia which may not be the optimal strategy given the current limitations.

Conclusions

This initial experience of using high-density mapping for arrhythmia management in patients with CHD allowed rapid acquisition of multiple maps with high accuracy to identify surgical scars and fibrosis. It was limited by the large atrial volumes, a high percentage of incomplete maps and a median of six arrhythmias per patient, resulting in a modest clinical success and need for re-ablation. Further improvements such as full 3D image integration and contact force assessment will make this novel multielectrode sequential mapping system hopefully a game changer in the near future.

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Conflict of interest: none declared.

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