Catheter ablation of ventricular arrhythmias originating from the region of DGCV-AIV via a Swartz sheath support approach

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Abstract

BACKGROUND For ventricular arrhythmias (VAs) originating from the left ventricular epicardium adjacent to the transitional area from the great cardiac vein to the anterior interventricular vein (DGCV-AIV), the most efficient catheter manipulation approach has not been fully elucidated. OBJECTIVE This study aimed to investigate a more appropriate catheter manipulation approach for DGCV-AIV VAs. METHODS One hundred twenty-three consecutive patients with DGCV-AIV VAs were retrospectively analyzed. All these patients were firstly mapped and ablated by conventional approach (Non-Swartz sheath support (NS) approach). When target sites not been reached, Swartz sheath support (SS) approach was attempted. If target sites still unreached, the hydrophilic coated guide wire and left coronary angiographic catheter-guided deep engagement of Swartz sheath in GCV to support ablation catheter was performed. RESULTS A total of one hundred three VAs (103/123, 83.74%) were successfully eliminated in DGCV-AIV. By NS approach, the tip of catheter reached DGCV in 39.84% VAs (49/123), reached target sites in 35.87% VAs (44/123), and achieved successful ablation in 30.89% VAs (38/123), which was significantly lower than by SS approach (88.61% (70/79), 87.34 % (69/79), and 84.81% (67/79), P<0.05). In left anterior oblique (LAO) view, angle between DGCV and AIV<83° indicated an inaccessible AIV by catheter tip with a predictive value of 94.5%. Width/height of coronary venous system>0.69 more favored a SS approach with a predictive value of 87%. CONCLUSION For RFCA of VAs arising from DGCV-AIV, the SS approach facilitates the catheter tip achieve target sites and contributes to a successful ablation.

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OBJECTIVE This study aimed to investigate a more appropriate catheter manipulation approach for DGCV-AIV VAs.

METHODS One hundred twenty-three consecutive patients with DGCV-AIV VAs were retrospectively analyzed. All these patients were firstly mapped and ablated by conventional approach (Non-Swartz sheath support (NS) approach). When target sites not been reached, Swartz sheath support (SS) approach was attempted. If target sites still unreached, the hydrophilic coated guide wire and left coronary angiographic catheter-guided deep engagement of Swartz sheath in GCV to support ablation catheter was performed.

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CONCLUSION For RFCA of VAs arising from DGCV-AIV, the SS approach facilitates the catheter tip achieve target sites and contributes to a successful ablation.

KEYWORDS Distal great cardiac vein, Anterior interventricular vein, Summit-communicating vein, Ventricular arrhythmias, Radiofrequency catheter ablation, Swartz sheath

Introduction

Radiofrequency catheter ablation (RFCA) is an effective and safe therapy for idiopathic ventricular arrhythmias (VAs). However, the ablation of VAs originating from the left ventricular epicardium adjacent to the transitional area from the great cardiac vein to the anterior interventricular vein (DGCV-AIV) can be challenging because of the complex anatomic structures of this region (adjacent to coronary arteries) and difficulty in manipulation of the ablation catheter in the small-lumen and tortuous coronary venous system[1,2].

It is reasonable to assume that any approach, which could assist ablation catheter going through the anatomic obstacles in the coronary venous system and aid catheter tip reaching more distal portion of DGCV-AIV, would improve the success rate of RFCA. Nevertheless, up to now, no systemic studies investigated the most appropriate manipulation approach for RFCA of VAs arising from DGCV-AIV.

Recent studies revealed that application of Swartz sheath could improve stability of catheter manipulation and enhance mapping and ablation efficiency in RFCA for VAs, for example, reversed U-curve technique of ablation catheter with the support of Swartz sheath for PSCs VAs[3], reversed S-curve technique of ablation catheter with the support of Swartz sheath close to the fossa ovalis for endocardial LV summit VAs[4]. Thus, we doubt whether the Swartz sheath support approach could be utilized in RFCA of DGCV-AIV VAs to achieve a more efficient ablation.

In this study, we aimed to evaluate the value and safety of the Swartz sheath support approach in mapping and ablation of DGCV-AIV VAs.

Methods

Study population

A total of 2768 patients (mean age 49.07±17.40 years) were referred for RFCA for symptomatic VAs in our center from December 2009 to December 2019. Among them, 123 consecutive VAs were confirmed arising from the DGCV-AIV based on systemic mapping results or successful ablation sites, and enrolled in this retrospective study. All patients had a normal ECG during sinus rhythm. Complete physical examination, echocardiography, exercise stress testing, or coronary angiography proved no structural heart diseases in any patient. Ethical approval was obtained from the hospital's ethics committee, and all patients gave written informed consent before operation.

Mapping and ablation

Electrophysiological study and ablation were performed after discontinuation of all antiarrhythmic drugs for at least five half-lives. A 6F decapolar catheter (4-mm interelectrode spacing) was inserted from the right internal jugular vein and placed in the coronary sinus. If clinical arrhythmias failed to occur spontaneously, intravenous isoproterenol infusion (2–5 mg/min) was administered. An irrigated-tip ablation catheter was advanced to the right ventricle and coronary venous system via antegrade transvenous approach and to the left ventricle via retrograde aortic approach. The RVOT, LV endocardium, aortic cusp, and DGCV-AIV were mapped with the ablation catheter to identify the earliest site of ventricular activation during VAs. Activation mapping was preferentially used to identify the origin during the procedure. Pace-mapping was also performed to capture the ventricular myocardium at the site of earliest activation. A suitable target for ablation was selected based on the earliest activation times during the arrhythmia combined with pace mapping. Once the origin of VAs was found within ASCs or PSCs, RFCA would be attempted by the irrigated-tip catheter in a power-controlled mode with a maximum temperature of 43 °C, preset power of 35 W, and flow rate of 17 ml/min. For DGCV-AIV, the irrigated-tip was applied with a flow rate of 30-60 ml/min, preset power of 25-30 W. CAG was performed in all cases to investigate distance from the catheter tip to adjacent coronary arteries before RFCA. Energy delivery was forbidden when the distance was less than 5mm. Coronary blood supply was routinely evaluated before and after ablation. If VAs were terminated or accelerated during the initial 10 s, radiofrequency delivery would be continued for 60 to 180 s. Otherwise, other targets were sought.

After successful ablation, intravenous administration of isoproterenol and programmed stimulation were performed to induce clinical VA. Acute success was defined as both absence of spontaneous or provoked clinical VA at the end of the procedure and the latter 48-hours period post-ablation on ECG Holter.

Swartz sheath support approach and non-Swartz sheath support approach

When the DGCV-AIV was considered the origin of ventricular arrhythmias, detailed mapping in DGCV-AIV was performed. For mapping and ablation in DGCV-AIV, two catheter manipulation approaches could be adopted, and shown in **Figure1** . The conventional approach, non-Swartz sheath support (NS) approach, was facilitated by delivering the tip of ablation catheter directly from the ostium of coronary sinus to DGCV-AIV to perform mapping and ablation. The Swartz sheath support (SS) approach was facilitated by engagement of Swartz sheath in GCV from the ostium of coronary sinus by ablation catheter. Then the ablation catheter and Swartz sheath were advanced alternately in GCV to reach the distal portion of DGCV-AIV to perform mapping and ablation. If the Swartz sheath still could not go through the GCV, the hydrophilic coated guide wire and Judkins' 4-left coronary catheter-guided deep engagement of Swartz sheath in GCV was conducted to support ablation catheter.

Definition of the location of DGCV-AIV origin

The DGCV-AIV origin of VAs was identified by mapping and ablation outcomes combined with retrograde venography of the coronary venous system. In our study, DGCV-AIV refers to the anatomy in the distal portion of the great cardiac vein, including four regions, DGCV1, DGCV2, summit-CV, AIV. DGCV1 is defined as the segment of DGCV at the epicardium of anterolateral wall of mitral annulus and DGCV2 as the segment of DGCV transecting the epicardial LV outflow region bounded by the bifurcation between the left anterior descending artery and left circumflex artery, and continued to DGCV1. Anterior interventricular vein (AIV) refers to the vein going along the anterior interventricular groove from cardiac apex to bottom, turning posteriorly and continuing as DGCV2. Summit-CV refers to the communicating vein (CV) between the aortic and pulmonary annulus, which is the extended tributary of the DGCV located distal to the origin of the AIV, see **Figure2** .

Anatomic obstacles for catheter manipulation in GCV

For catheter ablation of DGCV-AIV VAs, a thorough understanding of CVS anatomy is essential[1,2]. The coronary sinus is located at the posterior and inferior part of the epicardial mitral valve and collecting the blood from CVS, ends in the right atrium. There is a small folded tissue known as Thebesian valve at the ostium of the coronary sinus, which might occasionally be an obstacle to catheterization. A small left atrial vein named Marshall (or Marshall ligament) is the remnant of the embryonic left superior cardinal vein and drains into the coronary sinus. It is at the point where Marshall vein drains into coronary sinus that coronary sinus turns into the great cardiac vein, 29.15% of patients have a well-developed Vieussens valve at this site that might preclude ablation catheter advancement. The GCV goes along the lateral portions of the mitral valve and extends into DGCV at epicardium of the anterolateral portion of mitral annulus. It is reasonable to believe that a curved GCV morphology may limit the advancement of catheter. DGCV turns into AIV beneath the aortic valve cusp at the left ventricular summit. The angle between AIV and DGCV2 has great individual variability. It is observed that an acute angle between AIV and DGCV2 would prevent the ablation catheter reaching proximal AIV, on the contrary, an obtuse angle would facilitate catheter performing mapping and ablation in proximal AIV. Communicating vein refers to the very thin veins between the GCV and conus branch that drains to the small cardiac vein, and Summit-CV is a distinct CV that is located between the aortic and pulmonary annulus, distal to the transitional area between the GCV and the AIV, and in close association with the superior portion of the LV summit. Previous studies have revealed summit-CV can be the source of idiopathic ventricular arrhythmias. However, the very thin lumen of this vessel usually limits the detailed mapping and ablation in this region. Above all, hamper of venous valves (Thebesian valve and Vieussens valve), deflections of GCV, acute angle between DGCV and AIV, thin lumen of Summit-CV, are all potential anatomic factors preventing catheter ablation of DGCV-AIV VAs. Therefore, any method, which could assist ablation catheter overcoming these anatomic obstacles, would contribute to the successful ablation of DGCV-AIV VAs. **Figure2** .

In this study, the angle between AIV and DGCV, and width/ height of GCV in each patient was measured by three electrophysiologists independently in the individualized LAO view (under this view, the course of GCV was sufficiently unfolded and clearly visualized), a mean value was adopted for statistical analysis. The height of GCV was defined as the maximal vertical distance from the beginning of AIV to the proximal GCV. The width of GCV was defined as maximal transversal distance from lateral GCV to the maximal vertical line.

Follow-up

Each patient returned for evaluation in the hospital's outpatient department of cardiology 1 month after treatment. Twelve-lead ECG and 24-hour Holter monitoring were performed at the 3-month follow-up visit.

Statistical analysis

Continuous variables are expressed as mean±SD. Continuous variables were compared using a t test if a normal distribution was assumed or using a Mann-Whitney U test if a normal distribution was not assumed. Categorical variables were compared using the$x$ ^{2} test. A 2-tailed P¡0.05 was considered significant.

Results

123 consecutive cases of DGCV VAs undergoing mapping and ablation in our center were retrospectively reviewed in this study, shown in**Figure 3** . NS approach and SS approach were attempted in 123 cases and 79 cases respectively. By NS approach, DGCV-AIV target site reaching was obtained in 44 VAs (35.87%, 44/123) with successful ablation in 38 VAs (30.89%, 38/123) VAs. Via SS approach, DGCV-AIV target site reaching was obtained in 69 VAs (87.34%, 69/79) with successful ablation in 67 VAs (84.81%, 67/79). In 12 VAs, target sites failed to be reached by both NS approach and SS approach, the hydrophilic coated guidewire and Jukin's-4 left coronary angiographic catheter-induced deep engagement of Swartz sheath was applied. By this way, the irrigated catheter was delivered to distal sites of DGCV-AIV. Among these 12 VAs, target sites was achieved in 7VAs (58.33%, 7/12) with successful ablation in 5 cases (41.67%, 5/12). There were no significant differences in catheter tip reaching coronary sinus, proximal GCV, middle GCV by NS approach and SS approach. Of note, some distal sites of GCV (DGCV1, DGCV2, AIV, Summit-CV) could be more possibly reached by catheter tip via SS approach. A successful ablation case of DGCV-AIV VAs by SS approach post failed NS approach was shown in **Figure 4.**

Due to the obstacle of venous valves of CVS, middle GCV could not be reached in 13 VAs and in 7 VAs by NS approach and SS approach, respectively. Nevertheless, via hydrophilic coated guide wire and coronary angiograohic catheter-guided deep engagement of Swartz sheath, the obstacle of venous valve was overcome. Hydrophilic coated guide wire could easily go through the venous valves, angiographic catheter went along super smooth guidewire, which provided a backup force for Swartz sheath and facilitate the Swartz sheath reach the middle GCV.

By NS approach, catheter tip accessed DGCV2 in 43 patients, among which, catheter tip could achieve AIV in only 21 patients. Via SS approach, catheter tip accessed DGCV2 in 69 patients, and catheter tip could further achieve AIV in 30 patients. The patients with AIV reached by catheter tip were compared with the patients of AIV not reached (51 VAs: 72.05+-14.62deg vs 61 VAs: 108.73+-17.61deg). The angel between AIV and DGCV2 [?]83deg had a sensitivity of 94.1%, specificity of 77.0%, and accuracy of 94.5% for identifying the inaccessibility from DGCV2 to AIV, no matter SS approach or NS approached used, shown in **Figure2** .

Whether the GCV morphology would affect the catheter manipulation approach selected was also investigated. In 44 VAs with target sites reached by NS approach, a smaller Width/Height of CVS was more found. On the contrary, in 67 VAs with target sites reached by SS approach, a relative larger Width/Height of CVS was observed. A W/H of CVS>0.69 had a sensitivity of 91.0%, specificity of 68.2%, and accuracy of 87% for identifying a SS approach application, shown in **Figure2** .

Electrophysiological mapping and ablation

A series of mapping and ablation parameters of successful ablated DGCV-AIV VAs by NS approach and by SS approach were also compared.There were no significant differences in the local ventricular activation time relative to the QRS onset (V-QRS), ventricular capture ratio, pace-match leads, procedure time, RF duration, numbers of RF lesions and fluoroscopy time. The operation time in coronary venous system by SS approach was slightly longer than by NS approach,shown in**Table2** .

Complications during the procedure by NS approach and SS approach were also compared. There were no significant differences in occurrence of complications between these two groups (4/123, 3.25% vs 7/79, 8.86%, p>0.05). Via SS approach, coronary vein dissection happened on 3 patients and coronary vein rupture happened on 2 patient. The two patients of coronary vein rupture developed cardiac tamponade, but turned hemodynamic stable post emergent pericardiocentesis. One patient has severe chest pain with CAG showing an acute irreversible 50% coronary stenosis in LAD, another patient had an episode of chest tightness, and coronary angiography revealed coronary spasm of LCx, and relieved by intravenous nitroglycerin. By NS approach, coronary vein dissection happened on 2 patients and coronary vein rupture occurred on one patient. Coronary vein rupture caused delayed pericardial effusion but without unstable hemodynamics, thus pericardiocentesis was not performed. Coronary spasm occurred on 1 patient but relieved by intravenous nitroglycerin, shown in **Table4** .

Discussion

Major findings

This study reports for the first time that VAs arising from DGCV-AIV can be mapped and ablated by Swartz sheath support approach with high efficiency and success rate compared to the non-Swartz sheath support approach.

RFCA VAs arising from DGCV-AIV

A total of 2768 VAs received RFCA in our cardiac lab, and 4.44% VAs (123/2768) were found arising from the region of DGCV-AIV. Successful ablation was achived in 102 patients (102/123). As is well-known, DGCV-AIV is the epicardial part of LVOT, the myocardium near the DGCV-AIV can be a source of idiopathic VAs. Yamada T et al. studied 27 consecutive patients with VAs originating from the epicardial LVOT and achieved successful ablation within the DGCV in 14 patients[5]. Hachiya H et al. also reported successful catheter ablation of idiopathic VAs originating from the AIV[6]. More recently, Yuki K et al. reported that 14 patients were found to have summit-CV VAs and successful ablation were achieved in 10 (71%) patients[7]. Therefore, VAs arising from DGCV-AIV was not a rare phenomenon and cathether ablation is an effective treatment for DGCV-AIV VAs.

Catheter ablation approach for DGCV-AIV VAs

Previous studies have revealed that one key point for successful ablation of DGCV-AIV VAs is the structure of DGCV-AIV being sufficiently accessed and mapped. However, the existence of anatomic obstacles in the coronary venous system limited the ablation catheter manipulation and access to the target sites in this region. In some cases, even advancing the ablation catheter to the proximal GCV is difficult. In our study, due to the obstacle of venous valves, catherter tip could not reach the proximal-middle GCV by NS approach and SS approach in 6 patients. One study reported in one patient with DGCV VAs, because of the tortuous course of GCV, catheter ablation could not access the optimal target site of VAs[8]. Contact force catheter guided deep engagement with a steerable sheath in the DGCV was then performed. The contact force catheter and steerable sheath were advanced alternately, which overcame the deflections in GCV and resulted in the deep engagement of catheter tip to DGCV and successful ablation of DGCV VAs. However, this method had its limitations. In patients with small size coronary venous system, it could be challenging to manipulate the contact force catheter and steerable sheath, as both of which were much larger than the conventional irrigated catheter and sheath in diameter. Besides, the much harder characteristics of steerable sheath may more easily cause coronary vein dissection and rupture. Another study also reported anatomic obstacles restrained successful ablation of DGCV-AIV VAs[7]. Due to the very distal portion of DGCV are usually very thin and frequently inaccessible to an ablation catheter, Kazutaka A et al. delivered a 2F microcatheter into the vein as a landmark of the ablation sites and performed ablation in the nearby endocardial structures. However, by this approach, the elimination of these VAs usually requires ablation at multiple sites at adjacent structures and because of indirect ablation, the efficacy of RFCA was usually limited. In our research, we found that an aute angle between AIV and DGCV was also another anatomic obstacle difficult to overcome when cathter ablation was performed, for which, an appropriate manipulation approach remained investigated. In addition, we found in a situation of narrow elliptical shape of CVS (Width/Height>0.69), SS approach ensured a powerful backup force for ablation catheter, which could assist catheter tip overcome a partial anatomic impediments of coronary venous system and reach the target sites in DGCV-AIV more easily, contributed to a relative higher success rate of RFCA. Thus, it was more favorable than NS approach when RFCA of DGCV-AIV VAs.

It should be noted that when catheter ablation of DGCV-AIV VAs, anatomic obstacle is not the the only factor that limits successful ablation. In clinical practice, successful ablation of DGCV-AIV VAs is associated with a network of factors, including origin sites (epicardially or intramurally), distance to adjacent coronary artery, impedance during ablation and so on.

Complications of Swartz sheath support approach for DGCV-AIV VAs

Of note, a relative higher rate of cardiac vein dissection and rupture was observed in SS approach. We speculated that while SS approach application provided a better backup for catheter manipulation, it also increased the contract force of catheter tip to the coronary vein, contributing a higher incidence of coronary vein damage.

In our study, coronary injury was found in both groups. Though the safe distance from the catheter tip to the adjacent coronary artery has been demonstrated by coronary angiography, coronary injury is still a potential complication, which could not be neglected.

Study limitations

As the study was a retrospective research, results needed to be confirmed by prospective studies. Further studies with multicenter and larger sample sizes are needed to confirm the findings.

Conclusion

VAs arising from DGCV-AIV is not a rare phenomenon. For catheter ablation of DGCV-AIV VAs, the Swartz sheath support approach facilitates the access of target sites and improves the success rate of RFCA.

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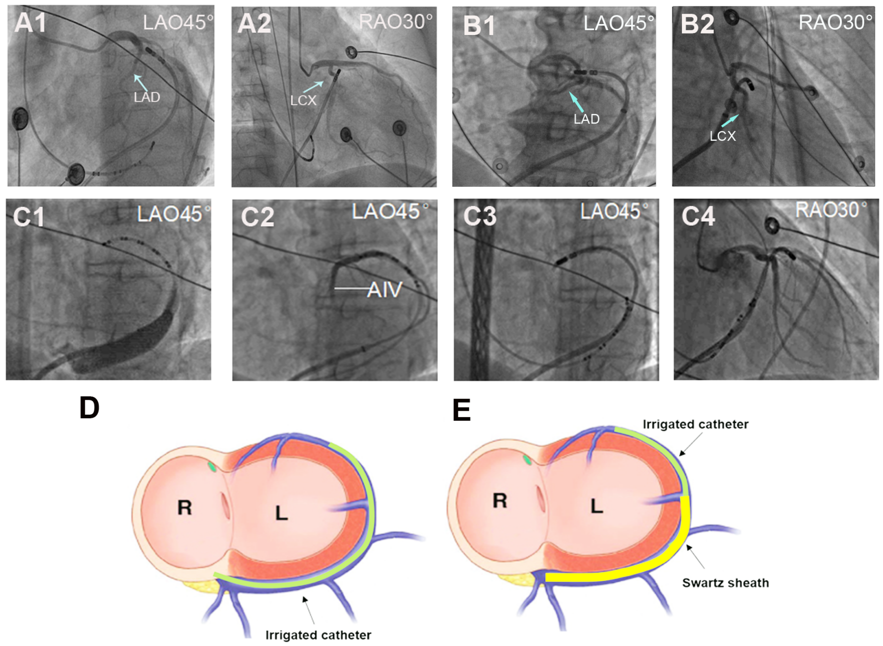
Figure legends

Figure1. Different approach for ablation catheter reaching target sites in DGCV. A. Manipulation of ablation catheter in GCV by non-Swartz sheath support (NS)approach. A1-A2. The tip of catheter was delivered to DGCV from the ostium of coronary sinus directly. B. Manipulation of ablation catheter in GCV by Swartz sheath support (SS)approach. B1-B2. The tip of catheter was delivered to summit-CV with the support from Swartz sheath in the GCV. C. Hydrophilic coated guide wire and left coronary angiographic catheter-guided deep engagement of Swartz sheath in GCV. C1. Due to the blockage of Vieussens valve (shown by coronary venography), even with the support of Swartz sheath, the catheter tip could not reach the middle part of GCV. C2. The hydrophilic coated guide wire and Judkin's 4-left coronary catheter was delivered through Swartz sheath and passed the Vieussens valve and reached the DGCV. C3-C4. Guided by hydrophilic coated guide wire and Judkin's catheter, the Swartz sheath was advanced alternately and passed the Vieussens valve, then the guidewire and Jukin's catheter was exchanged with ablation catheter to performed mapping and ablation in DGCV. D. Schema of NS approach for DGCV-AIV VAs. Targeting DGCV-AIV VAs via advancing ablation catheter from ostium of coronary sinus directly. E. Schema of SS approach for DGCV-AIV VAs. Targeting DGCV-AIV VAs via advancing ablation catheter from ostium of coronary sinus with the support from Swartz sheath. LAD, left anterior descending artery, LCX, left circumflex artery. LAO, left anterior oblique, RAO, right anterior oblique.

Figure2.Anatomy of DGCV-AIV andanatomic obstacles preventing catheterization in GCV.A-C. Anatomy of DGCV-AIV. D-G. Anatomic obstacles preventing catheterization in GCV. D. Angle formed between DGCV and AIV, and an angle <83deg prevented the ablation catheter advancing from DGCV into AIV with. E. Different morphology of GCV, and Width/Hight¿0.69 more favored the application of SS approach. F. Venous valve (Vieussens valve) in GCV. G. Thin lumen of summit-CV. DGCV, distal great cardiac vein; AIV, anterior interventricular vein; summit-CV, communicating vein in left ventricular summit. RVOT, right ventricular outflow tract, LVOT, left ventricular outflow tract, TA, tricuspid annulus, MA, mitral annulus, CS, coronary sinus.

Figure3. Flowchart of mapping and ablation procedure in this study.

Figure4. An example of successful ablation of premature ventricular complex (PVC) originating from Summit-CV by SS approach. A. Twelve-lead ECG 3 morphology of the clinical PVC. The PVC showed R wave in II, III, aVF, V4-V6, rS morphology in lead V1, the precordial transition zone of PVC was earlier than sinus beat. B. By NS approach, the irrigated catheter could reach the distal portion of GCV. SS approach was then applied in this patient. By SS approach, the irrigated catheter reached the target site in summit-CV. The local ventricular activation time recorded at the summit-CV preceded the onset of the QRS complex by 52 ms, and perfect pace-match was achieved by pacing at summit-CV. C1-C3. Fluoscopic view of target site in summit-CV. D. Radiofrequency energy delivered on target site for 5s led an acute disappearance of target PVCs.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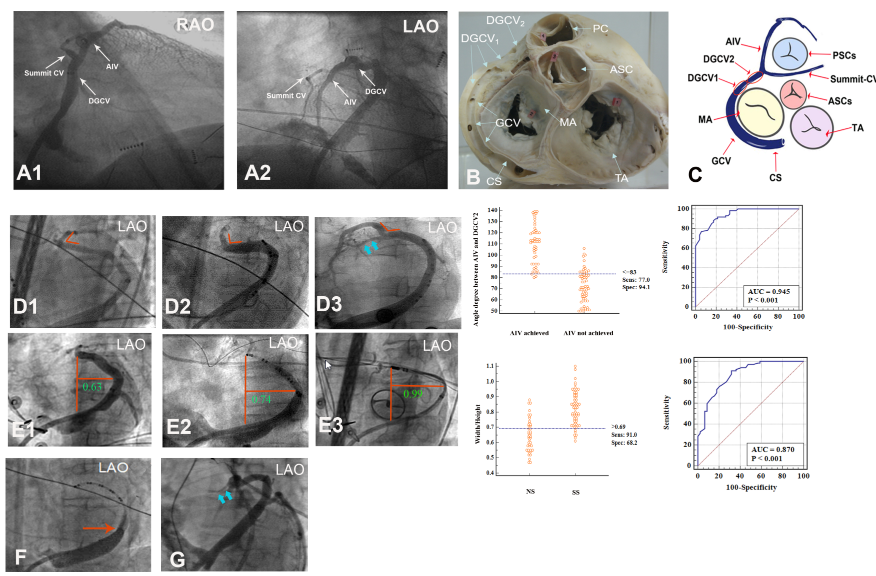
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D1
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D3
Angle degree between AIV and DGCV2
<=83
Sens: 77.0
Spec: 94.1
AIV achieved
AIV not achieved
Sensitivity
AUC = 0.945
P < 0.001
100-Specificity
LAO
E1
LAO
E2
LAO
E3
0.63
0.74
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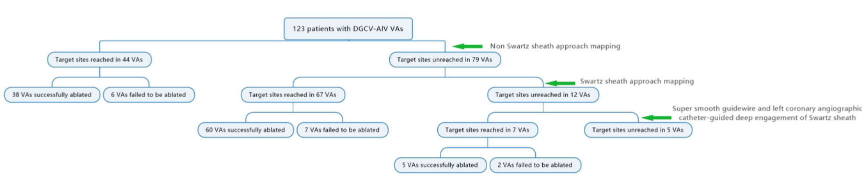
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Non Swartz sheath approach mapping
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Target sites unreached in 79 VAs
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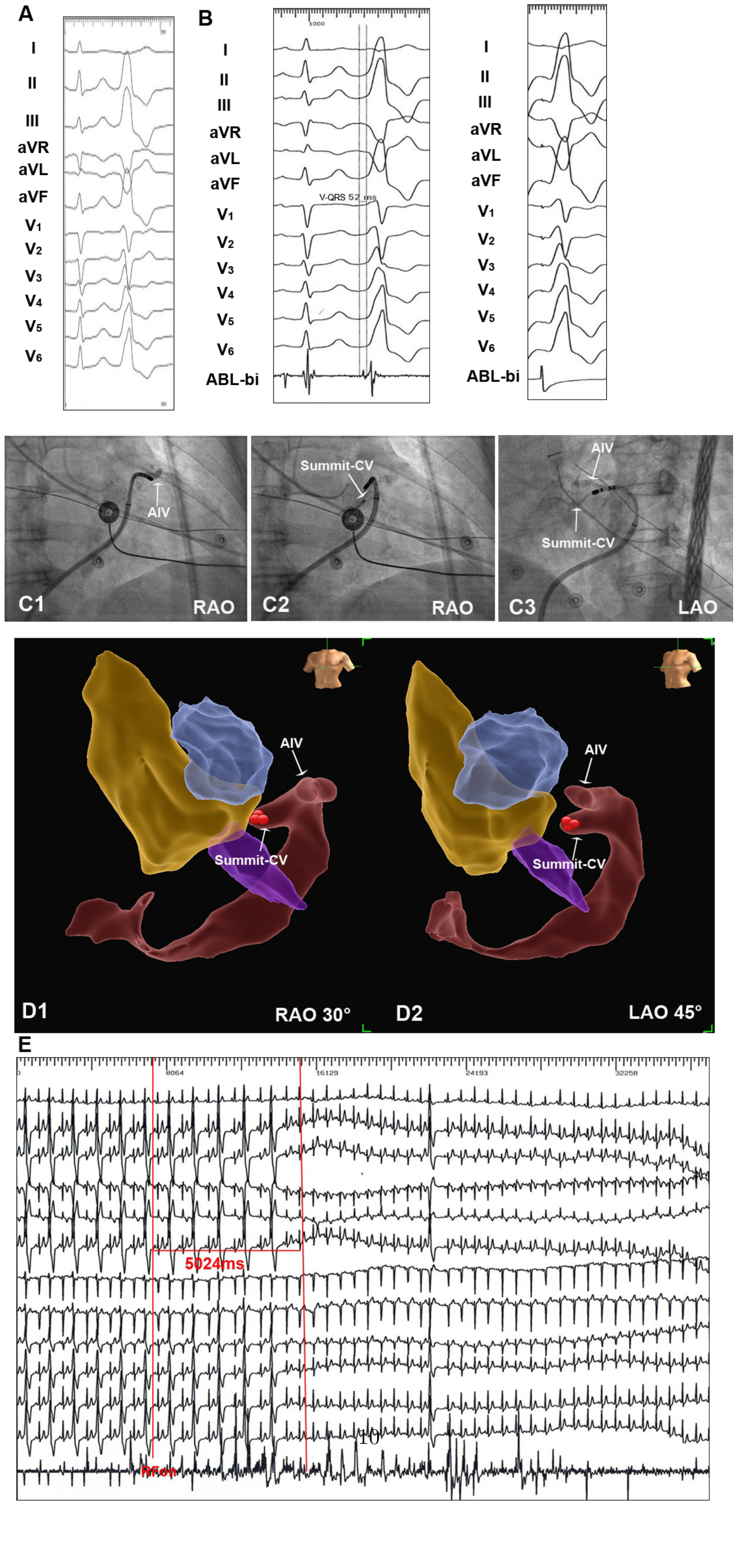
6 VAs failed to be ablated
Swartz sheath approach mapping
Target sites reached in 67 VAs
Target sites unreached in 12 VAs
60 VAs successfully ablated
7 VAs failed to be ablated
Super smooth guidewire and left coronary angiographic catheter-guided deep engagement of Swartz sheath
Target sites reached in 7 VAs
Target sites unreached in 5 VAs
5 VAs successfully ablated
2 VAs failed to be ablated


A
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
B
1000
V-QRS 52 ms
ABL-bi
AIV
Summit-CV
C1
C2
C3
RAO
LAO
D1
D2
RAO 30°
LAO 45°
E
8064
16129
24193
32258
5024ms
RFon

Hosted file

`final table2.docx` available at https://authorea.com/users/471339/articles/562856-catheter-ablation-of-ventricular-arrhythmias-originating-from-the-region-of-dgcv-aiv-via-a-swartz-sheath-support-approach