Three-dimensional Mapping System Facilitated Superior Approach for Radiofrequency Ablation of Tachyarrhythmia in Patients without Inferior Vena Cava Access

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Abstract

Catheter ablation for tachyarrhythmia via superior approach has been used in patients without possible inferior vena cava access such as in cases of venous occlusion or complex anomaly. Difficulty in catheter manipulation, instability, number of required vascular access, and radiation exposure of operator had been described in the procedure. Application of three-dimensional (3-D) mapping system in catheter ablation via superior approach could navigate the guiding catheter and provide more precise ablation. We reported four cases receiving catheter ablation due to atrioventricular nodal reentry tachycardia, atrial fibrillation and right ventricular arrhythmia via superior approach facilitated by 3-D mapping system with fewer vascular access and catheters.

1. Introduction

Azygos and hemiazygos continuation of the inferior vena cava (IVC) occurs in up

to 0.6% of the population. [1] Interruption of the IVC is uncommon but one might come across this condition during electrophysiology procedures. Anatomical anomalies such as bifurcating or tortuous veins, or IVC occlusion by prosthetic material or thrombus could also make femoral access impossible in catheter ablation.

Previous case reports had demonstrated that it is feasible for catheter ablation via superior approach, either via jugular or subclavian vein, in atrioventricular nodal reentry tachycardia (AVNRT) [2] [3] [4] [5], accessory pathway [6] [7], typical atrial flutter [8], atrial fibrillation [9] [10], and right ventricular arrhythmia. [11] [12][13]

A superior approach with an advanced three-dimensional (3-D) mapping system might reduce the number of vascular access in these cases. In this case series, we presented four tachyarrhythmia cases with interruption of the IVC or bilateral lower leg deep vein thrombosis. All the tachyarrhythmias were successfully eliminated by catheter ablation using superior approach under the guidance of 3-D mapping system.

The present study was approved by the Institutional Review Board at Taipei Veterans General Hospital, Taipei, Taiwan.

2. Case series

Case 1

A 50- year- old woman had intermittent palpitations for several days and subsequently underwent electrophysiology study (EPS). Both right and left femoral veins were accessed but the diagnostic catheters could not be advanced to inferior vena cava (IVC). Venography revealed anomalous venous drainage of both femoral veins into azygous and hemiazygos veins with IVC agenesis. (Figure 1A and 1B). Owing to small lumen of azygos veins, only one decapolar catheter could be advanced through hemiazygos vein (via left subclavian vein to SVC) to the coronary sinus (CS). Programmed stimulation was done via coronary sinus pacing which confirmed the dual atrioventricular node conduction and subsequently induced AVNRT (Figure 1C). Another vascular access was established in the right internal jugular vein for the ablation catheter. His bundle signal was recorded and mapped using the 3-D mapping system (EnSite NavX system) (Figure 1D and 1E). Radiofrequency energy was applied over the low Koch area with transient accelerated junctional rhythm. Slow pathway was successfully eliminated and the tachycardia was no longer inducible after the ablation.

Case 2

This was a 48- year- old woman experiencing worsening palpitations for 2 months. She was recently diagnosed with bilateral lower leg deep vein thrombosis and on anticoagulation therapy using rivaroxaban. Venography before the EPS showed thrombus with total occlusion at left interval jugular vein with collaterals to azygos vein. Right internal jugular vein was used as vascular access for CS and ablation catheters (Figure 2A). Basic electrophysiology study showed typical slow-fast AVNRT induced by CS S1S1 and RV S1S1 burst pacing. After 3-D mapping (EnSite NavX system) and identification of His region, cryoablation (Freezor Max, Medtronic CryoCath LP, Canada) was applied at the low Koch triangle area. (Figure 2B). After ablation, tachycardia could no longer be induced.

Case 3

This was a 16- year- old man who was diagnosed with Tetralogy of Fallot. He underwent multiple surgical repairs and received epicardial pacemaker implantation for complete atrioventricular block in 2002. He complained of episodes of sudden onset chest tightness and palpitations. Ventricular tachycardia (VT) was recorded at the emergency room, hence, EPS was done. Venography was performed from the left femoral vein access and showed tortuous left hemiazygous vein with total occlusion from the iliac vein to the proximal inferior vena cava. Vascular access was established in the left internal jugular and subclavian veins. The electroanatomical map of the right ventricle was created using CartoSound module, 3.5mm open-irrigated Thermocool (Thermocool, Biosense Webster, CA, US) ablation catheter and SoundStar catheter. Monomorphic VT was induced during the EPS (Figure 3A). The VT circuit was localized in the area around the tricuspid annulus and right ventricular outflow tract (RVOT) patch. (Figure 3B). Radiofrequency energy was applied at the isthmus of the circuit and eliminated the VT successfully (Figure 3C). Post-ablation inducibility test with RV S1S4 was negative. [13]

Case 4

A 63- year- old man with persistent atrial fibrillation (AF) and history of transient ischemic attack (TIA) was admitted for pulmonary vein isolation (PVI). Venography showed interruption of IVC with azygos continuation. The CS catheter placement was through the azygos vein. The right internal jugular vein was cannulated and transseptal puncture was done using SL3 sheath and transseptal puncture needle (150 degree) (Figure 4A and 4B). After transseptal puncture, synchronized cardioversion (100J) was done to restore sinus rhythm. Four PVI was performed successfully via right internal jugular vein approach and post-ablation induction test was negative (Figure 4C).

3. Discussion

Prior study has shown that catheter ablation via superior approach for AVNRT is safe and feasible. [2] Femoral approach with IVC interruption and azygos continuation may be possible but has disadvantages including (1) instability and difficulty in manipulation of catheters, (2) increased fluoroscopy time and radiation exposure, and (3) patient discomfort due to the numerous catheters.

Superior approach has been reported in catheter ablation of VT with IVC access issues including anatomical anomalies (bifurcating or tortuous veins), IVC interruption or agenesis, or IVC obstruction by prosthetic material or thrombus. [11] [12][13] [14] Using multielectrode and large curves catheters is recommended to better define the scar and border zone areas, and in accessing the RVOT. [12]

Hong Euy Lim et al. demonstrated the safety and feasibility of AF ablation via the superior approach in patients with complete interruption of the IVC. Transseptal puncture via superior approach can be challenging and requires better support with (1) Brockenbrough needle (manually bent with 150°) toward the fossa ovalis (FO), and (2) a stiffer and angulated sheath, such as the Mullins sheath, SL3 sheath, or superior transseptal access system. Additionally, a steerable sheath can make transseptal puncture and catheter manipulation in the left atrium easier. In cases of difficult transseptal puncture, utilizing transesophageal echocardiography (TEE) can provide greater certainty of safe puncture and prevent major complications. [9] [10] Integration of the 3-D mapping system with pre-acquired MR or MDCT images can improve navigation of the mapping catheter within the atria. It can also provide better accuracy of lesion placement to ensure continuity of linear ablation over the complex anatomy of the PVs and the surrounding LA antrum. [15] [16]

In our study, we present four cases who underwent catheter ablation via superior approach including AVNRT, monomorphic VT, and persistent AF with 3-D mapping system (Table 1). In these four cases, we used different vascular access including right internal jugular vein, right subclavian vein, and right femoral with azygos continuation. We chose superior approach because of (1) IVC interruption, (2) bilateral femoral venous thrombosis, (3) bilateral iliac vein total occlusion, and (4) highly tortuous vessel. Compared with conventional fluoroscopy-guided ablation, 3-D mapping system in these complex cases can provide precise cardiac anatomy and target ablation area with fewer intra-cardiac catheters. Only two catheters via two vascular access were required in our cases, with utilization of 3D mapping. In the case of VT and persistent AF, long sheaths were needed to facilitate the mapping and ablation. Complications such as puncture site hematoma, significant vessel damage, pericardial tamponade, and aortic or atrial perforation may occur in cases such as the ones presented due to the complexity of the access and ablation approach but none were recorded in our cases. All were also successfully ablated.

4. Conclusion

Our case series suggested that it is feasible and safe to perform AVNRT, VT and AF ablation via superior approach with limited vascular access and catheters under guidance of 3-D mapping system in patients with unfavorable femoral vein and IVC anatomy.

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FIGURE LEGEND

FIGURE 1

1A, 1B: Venography showed absence of IVC with azygos and hemiazygos continuation. * Represented quadripolar catheter in agenesis of IVC.

1C: The electrophysiology tracing suggested slow-fast AVNRT.

1D: The fluoroscopy showed the ablation catheter position over low Koch area using superior approach via right internal jugular vein and CS catheter via left femoral approach.

1E: 3-D mapping system created geometry of right atrial and localized the ablation site.

FIGURE 2

2A: Right internal jugular vein approach with CS and ablation catheter.

2B: Cryoablation at low Koch area with guidance of 3-D mapping system.

Abbreviation the same as Figure 1, LAOleft anterior obliqueRAOright anterior oblique.

FIGURE 3

3A: Clinical monomorphic sustained VT with LBBB pattern, inferior axis and QS waves in all precordial leads.

3B: The activation map demonstrated the position of critical isthmus surrounding the tricuspid annulus and RVOT patch.

3C: Fluoroscopic image of target area between superior tricuspid annulus and RVOT.

PApulmonary arteryRAright atrium; RVOTright ventricular outflow tractTAtricuspid annulusVTventricular tachycardia.

FIGURE 4

4A: Reconstructed 3-D geometry of IVC interruption with azygos continuation.

Coronary sinus catheter was positioned from femoral vein with a SR-0 long sheath.

(Green line) Ablation catheter was advanced through the SL-3 long-sheath to the LA.

(Yellow line).

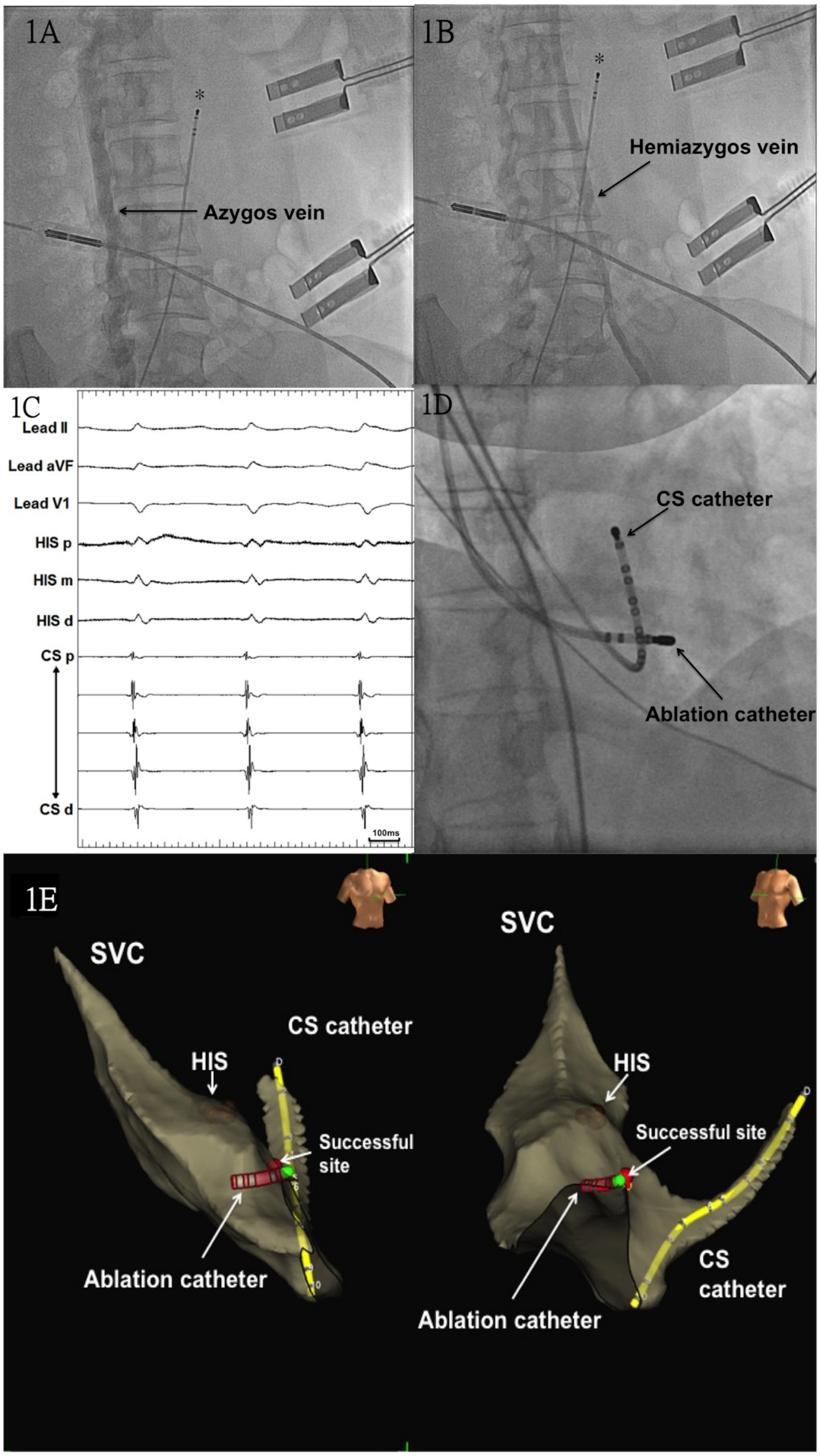
4B: Fluoroscopy of transseptal procedure via superior approach.

4C: Voltage mapping after circumferential pulmonary vein isolation.

Table 1. Baseline characteristics and procedure details

Baseline characteristics	Case1	Case2	Case3	Case4
Age	50	48	16	60
Gender (Male)	Female	Female	Male	Male
Arrhythmia type	AVNRT	AVNRT	Monomorphic VT	AF
Vascular access (number)	Right internal jugular, left femoral (2)	Right internal jugular vein (2)	Left internal jugular Left subclavian (2)	Right femoral vein Right jugular vein (2)
Ablation catheter	4mm ablation catheter	8mm Cryoablation catheter	3.5mm open-irrigated Thermocool	3.5mm Coolpath
Ablation site	Low Koch	Low Koch	Area between the free wall of RVOT and tricuspid annulus	4 PV isolation
Ablation result	Successful	Successful	Successful	Successful
3D mapping	Ensite Navx	Ensite Navx	Carto	Ensite Navx
Catheter amount	2	2	2	2
Long sheath	-	-	+	+(SL-3)
Procedure time	35 min	136 min	127 min	91min
Fluoroscopic time	16.5 min	62.5 min	80.5 min	57.2 min
Complication	None	None	None	None
Recurrence	None	None	None	Recurrence (7 months post-ablation)

Figure 1


1A
Azygos vein
1B
Hemiazygos vein
1C
Lead II
Lead aVF
Lead V1
HIS p
HIS m
HIS d
CS p
CS d
100ms
1D
CS catheter
Ablation catheter
1E
SVC
CS catheter
HIS
Successful site
Ablation catheter
SVC
HIS
Successful site
CS catheter
Ablation catheter

Fugure 2

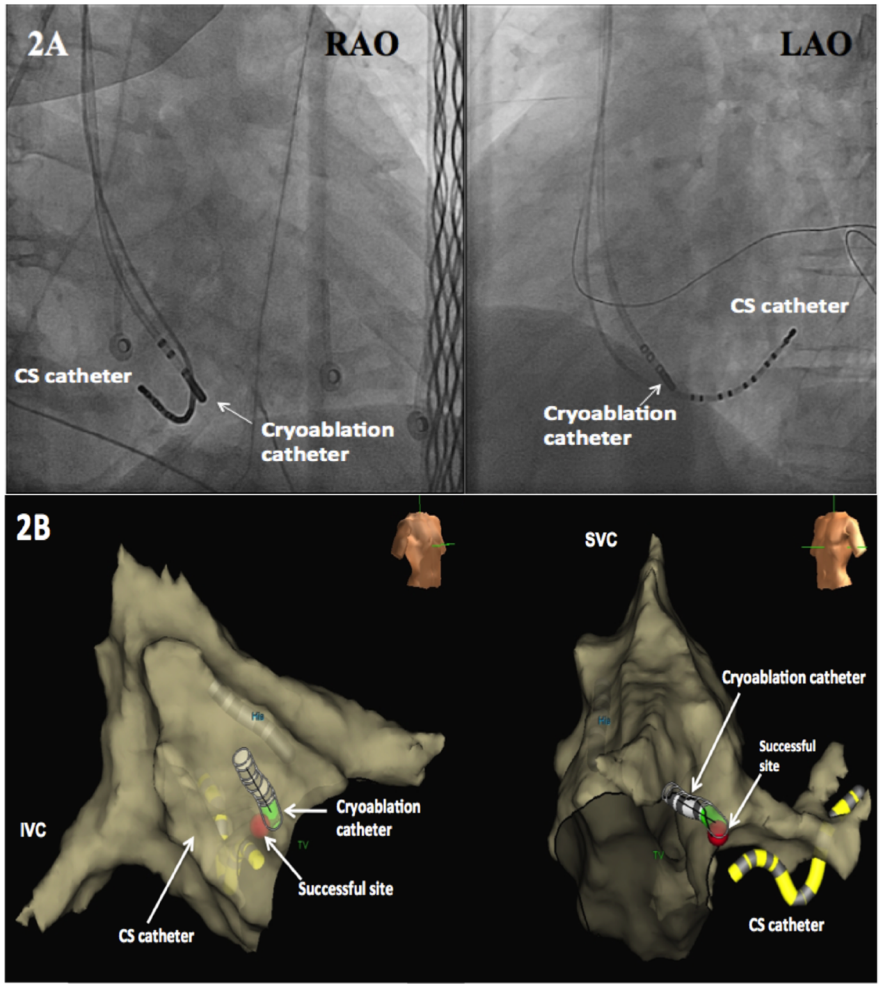
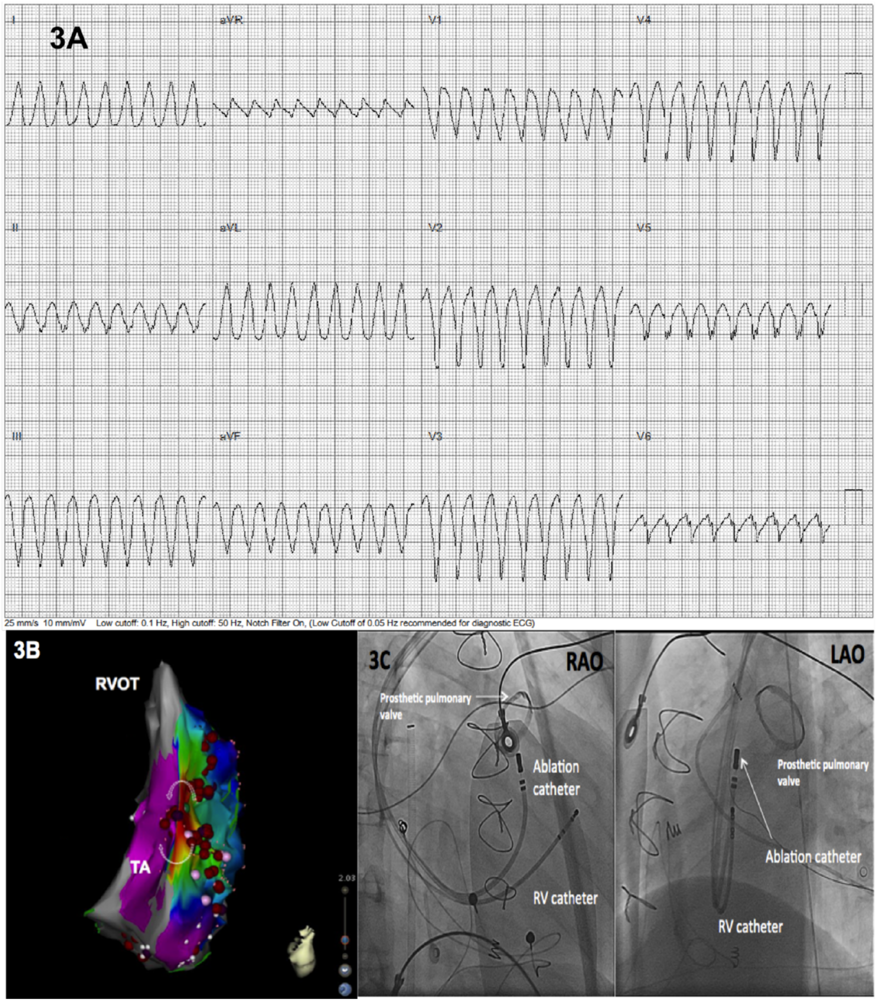
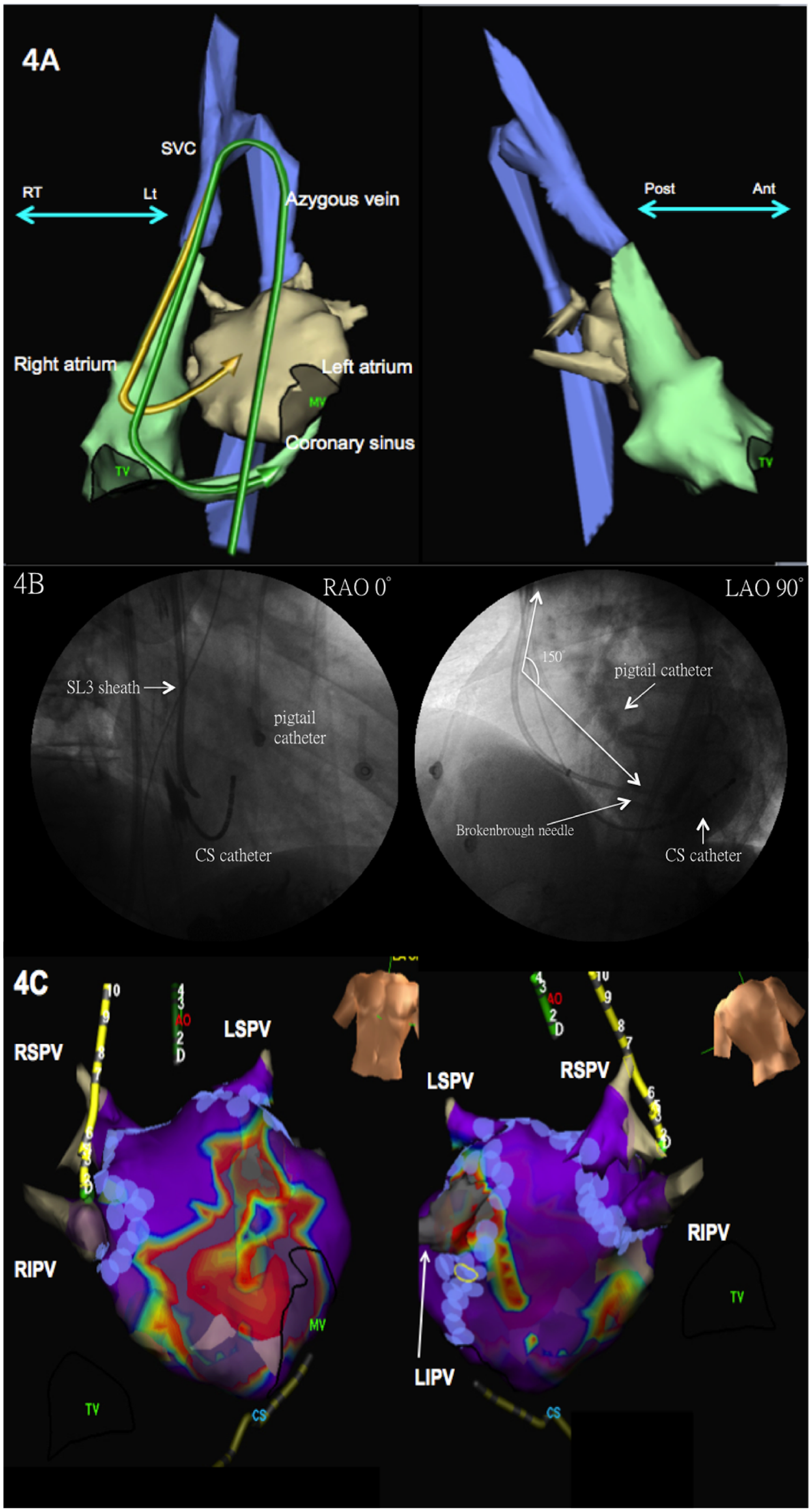

2A
RAO
CS catheter
Cryoablation catheter
LAO
CS catheter
Cryoablation catheter
2B
IVC
Cryoablation catheter
Successful site
CS catheter
SVC
Cryoablation catheter
Successful site
CS catheter

Figure 3


3A
I
aVR
V1
V4
II
aVL
V2
V5
III
aVF
V3
V6
25 mm/s 10 mm/mV Low cutoff: 0.1 Hz, High cutoff: 50 Hz, Notch Filter On, (Low Cutoff of 0.05 Hz recommended for diagnostic ECG)
3B
RVOT
TA
3C
RAO
Prosthetic pulmonary valve
Ablation catheter
RV catheter
LAO
Prosthetic pulmonary valve
Ablation catheter
RV catheter

Fgure 4


4A
SVC
RT
Lt
Azygous vein
Right atrium
Left atrium
MV
Coronary sinus
TV
Post
Ant
TV
4B
RAO 0°
SL3 sheath
pigtail catheter
CS catheter
LAO 90°
150°
pigtail catheter
Brokenbrough needle
CS catheter
4C
RSPV
LSPV
RIPV
MV
TV
CS
LSPV
RSPV
RIPV
LIPV
TV
CS