SUPPLEMENTAL MATERIAL

Supplemental Figure Legends:

Figure S1. Electrocardiographic findings. A, Rhythm strip showing P wave (red arrowheads) dissociated from the QRS complex, suggesting complete AV block (patient 3). **B-C,** Rhythm strips of patient 5 (**B**) and patient 7 (**C**) also showed complete AV blocks. **D,** Electrocardiogram V1 and V2 were recorded from the atrial wire of a temporary epicardial pacemaker. V2 lead showed RA EGMs with a cycle length shorter than the QRS complexes compatible with complete AV block (patient 4). **E,** Rhythm strip of patient 6 showed dual P waves, one with lower amplitude (blue arrowheads) and conducting to the ventricle, and the other with higher amplitude (red arrowheads) and dissociated from the QRS complex. **F,** Holter monitoring of patient 6 showed paroxysmal AV block with non-conducted P waves (red arrowheads) and an RR interval of 4.98 s. **G,** Holter monitoring of patient 7 showed a wide QRS complex tachycardia with right bundle branch block morphology. AV indicates atrioventricular; EGM, electrogram; and RA, right atrium.

Figure S2. Fluoroscopic images and intracardiac electrograms of patient 1. A, Left anterior oblique (40 degrees) and right anterior oblique (30 degrees) fluoroscopic images showing the positions of electrode catheters during the electrophysiologic study. **B,** Atrial pacing from the distal CS electrodes (PCL = 700 ms) showed conduction to the RA FW (where distal HRA electrodes were located), RA septum, and the ventricle without conduction to the PL RA (where proximal HRA electrodes were located, red arrowheads). **C,** Atrial pacing at RAA (PCL = 500 ms) captured the PL RA (red arrowheads) without conduction to the distal HRA, LA/CS, and ventricle. **D,** Chest radiographs (posteroanterior and left lateral view) showed that the atrial lead was fixed at the posteroseptum of RA around the CS ostium and the ventricular lead was fixed at the apex of the right ventricle.

CS indicates coronary sinus; FW, free wall; HRA, high right atrium; LA, left atrium; PCL, pacing cycle length; PL, posterolateral; RA, right atrium; and RAA, right atrial appendage.

Figure S3. Fluoroscopic images and intracardiac electrograms of patient 2. A, After a spontaneous termination of AF, atrial pacing at the HRA electrodes (HRA 5–6, PCL = 400 ms) showed 1:1 AV conduction. **B-C,** Differential pacemapping was done at multiple atrial sites of the RA. (**B**) Atrial potential of the RA PW (red arrowheads) was dissociated from LA/CS and ventricle. (**C**) Atrial activity of the RA septum (TA 05:00, blue arrowheads) conducted to the ventricle with a normal HV interval, while it was dissociated from the PL RA. **D,** AF was localized to the LA/CS and RA FW occurred spontaneously and induced a rapid ventricular response.

AF indicates atrial fibrillation; AV, atrioventricular; CS, coronary sinus; FW, free wall; HRA, high right atrium; HV, His to ventricular; LA, left atrium; PCL, pacing cycle length; PL, posterolateral; PW; posterior wall; RA, right atrium; and TA, tricuspid annulus.

Figure S4. Recording from patient 3. A, Junctional rhythm (cycle length = 1030–1190 ms) with retrograde atrial activation (blue arrowhead) was observed, and right bundle potential was recorded at the His electrodes. Atrial activation of the PL RA (red arrowheads) was dissociated from those of the septum and LA/CS, and it was not conducted to the ventricle. **B,** Atrial pacing at the RA septum (PCL = 700 ms) showed 1:1 AV conduction to the LA/CS and ventricle without conduction to the PL RA. **C,** Atrial pacing at the PL RA (PCL 700 ms) captured the dissociated RA (red arrowheads) without conduction to the LA/CS (blue arrowheads) or to the ventricle.

AV, atrioventricular; CS, coronary sinus; LA, left atrium; PCL, pacing cycle length; PL, posterolateral; and RA, right atrium.

Figure S5. Recording from patient 4. A, Junctional escape rhythm with normal HV interval (40 ms, black arrowheads) was observed. At distal HRA electrodes, atrial tachycardia continued at a cycle length longer than that of the proximal HRA electrodes, suggesting conduction block between the PL and FW RA. After electrical cardioversion, intra-RA dissociation of the PL RA from the septum and LA/CS was observed during sinus rhythm, although detailed mapping at multiple atrial sites could not be done due to the lack of atrial EGM at the HRA and CS electrodes. **B,** Atrial pacing at distal CS (PCL = 1000 ms) showed group beating due to Wenckebach AV conduction. **C,** Atrial pacing at proximal HRA (PCL = 1000 ms) was not conducted to the ventricle, and junctional escape rhythm (cycle length = 1120 ms) with a normal HV interval (40 ms, black arrowheads) was recorded.

AV indicates atrioventricular; CS, coronary sinus; EGM, electrogram; FW, free wall; HRA, high right atrium; HV, His to ventricular; LA, left atrium; PCL, pacing cycle length; PL, posterolateral; and RA, right atrium.

Figure S6. Recording from patient 5. **A,** Right anterior oblique (30 degrees) fluoroscopic image showing the position of the electrode catheters. **B,** Atrial pacing at the proximal CS (PCL = 500 ms) showed 1:1 AV conduction, and a dissociated atrial activity with a different cycle length (red arrowheads, 644 ms) was observed at the proximal HRA electrodes (red arrowheads). **C,** Atrial pacing at distal CS (PCL = 600 ms) was not conducted to the proximal CS (blue arrowheads), septum, and ventricle. Simultaneously, the distal CS pacing captured the HRA electrodes (red arrowheads) via inter-atrial conduction through the Bachmann's bundle. **D,** Atrial pacing at HRA electrodes (HRA 5-6, PCL = 380 ms) was not conducted to the septum, LA/CS, and ventricle. **E,** Rapid pacing at the proximal CS (PCL = 340 ms) under isoproterenol infusion induced AF localized to the proximal CS and septum.

AF indicates atrial fibrillation; AV, atrioventricular; CS, coronary sinus; HRA, high right atrium; LA, left atrium; and PCL, pacing cycle length.

Figure S7. Recording from patient 7. A, Left anterior oblique fluoroscopic image (40 degrees) showing the position of the electrode catheters. A 20-pole Halo catheter was placed around the TA, a decapolar catheter was engaged into the CS, and a deflectable ablation catheter was used for mapping at multiple atrial sites. **B,** Atrial activity of the Halo electrodes was dissociated from the LA/CS and was not conducted to the ventricle. Junctional escape rhythm with retrograde atrial activation (blue arrowheads) was observed, and intermittent atrial ectopy from the LA/CS (green arrowheads) conducted to the ventricle. The HV interval was 38 ms (black arrowheads). **C,** Atrial pacing at the low lateral FW of RA (PCL = 600 ms) captured the dissociated RA (red arrowheads) without conduction to the LA/CS and ventricle. **D,** Atrial pacing at the proximal CS (PCL = 500 ms) conducted 1:1 to the ventricle and simultaneously to the dissociated RA (red arrowheads). **E-H,** Differential pacemapping at multiple RA sites. When the catheter was placed at the RA PW (**E**), RA FW (TA 12:00) (**F**), RA FW (TA 9:00) (**G**), or high septum (**H**), the local potential (red arrowhead) were dissociated from the LA/CS and did not conduct to the ventricle. However, atrial potentials at the mid septum (TA 3:00) (**I**) and the CS ostium (**J**) (blue arrowheads) were conducted to the ventricle.

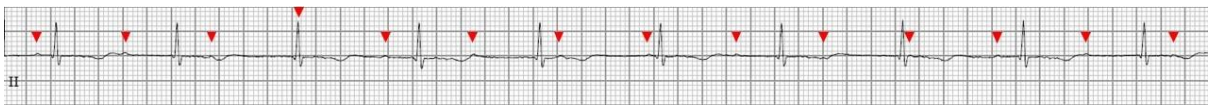
CS indicates coronary sinus; FW, free wall; HV, His to ventricular; LA, left atrium; PCL, pacing cycle length; PW, posterior wall; RA, right atrium; and TA, tricuspid annulus.

Figure S8. Recording from patient 5. Paroxysmal AV block was recorded during Holter (upper image) and telemetry monitoring (lower image).

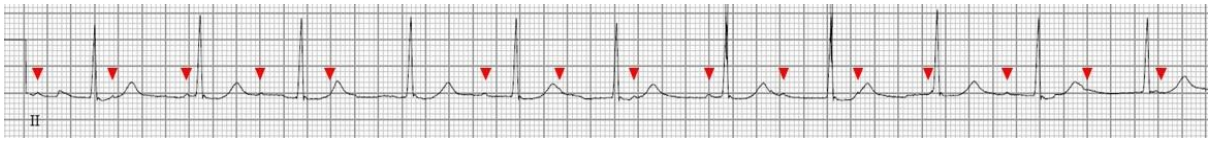
AV indicates atrioventricular.

Figure S1.

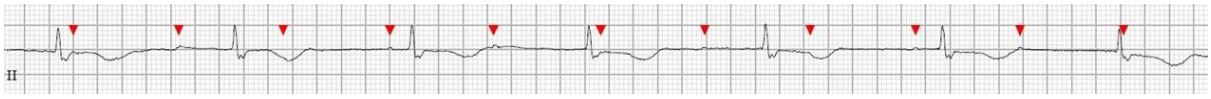
A



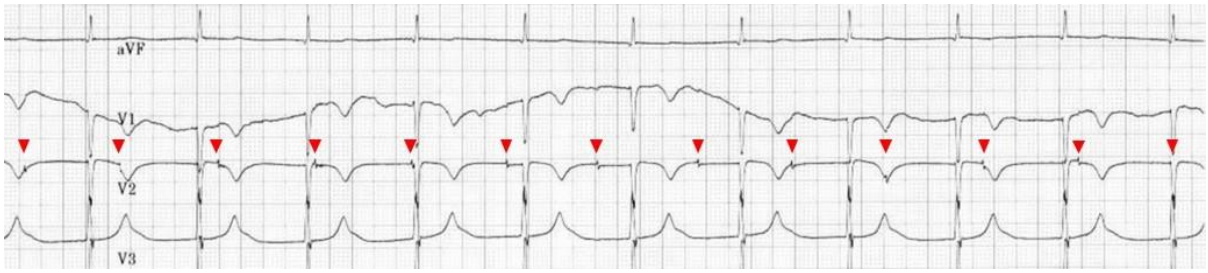
B



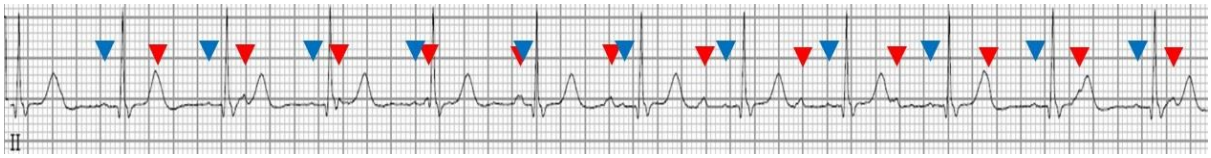
C



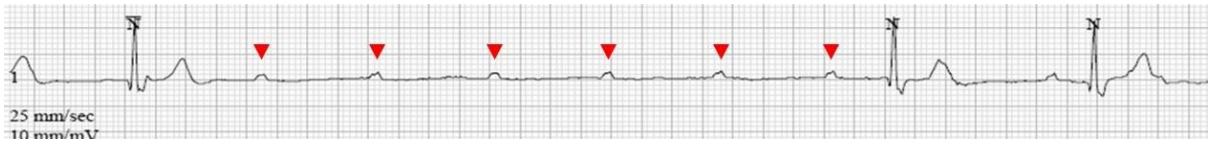
D



E



F



G

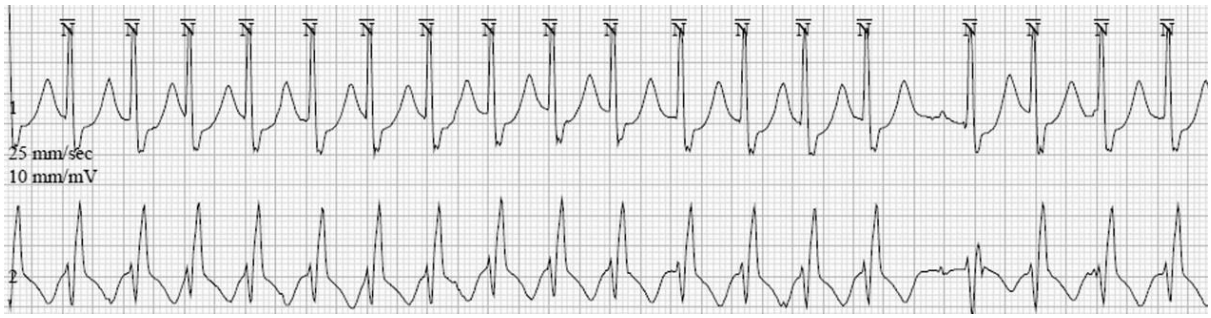
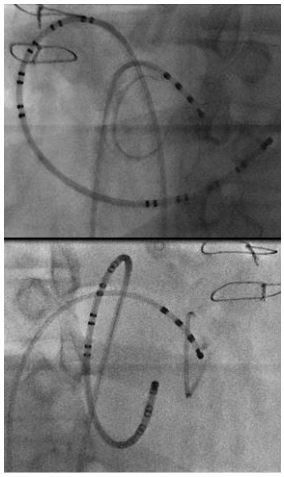
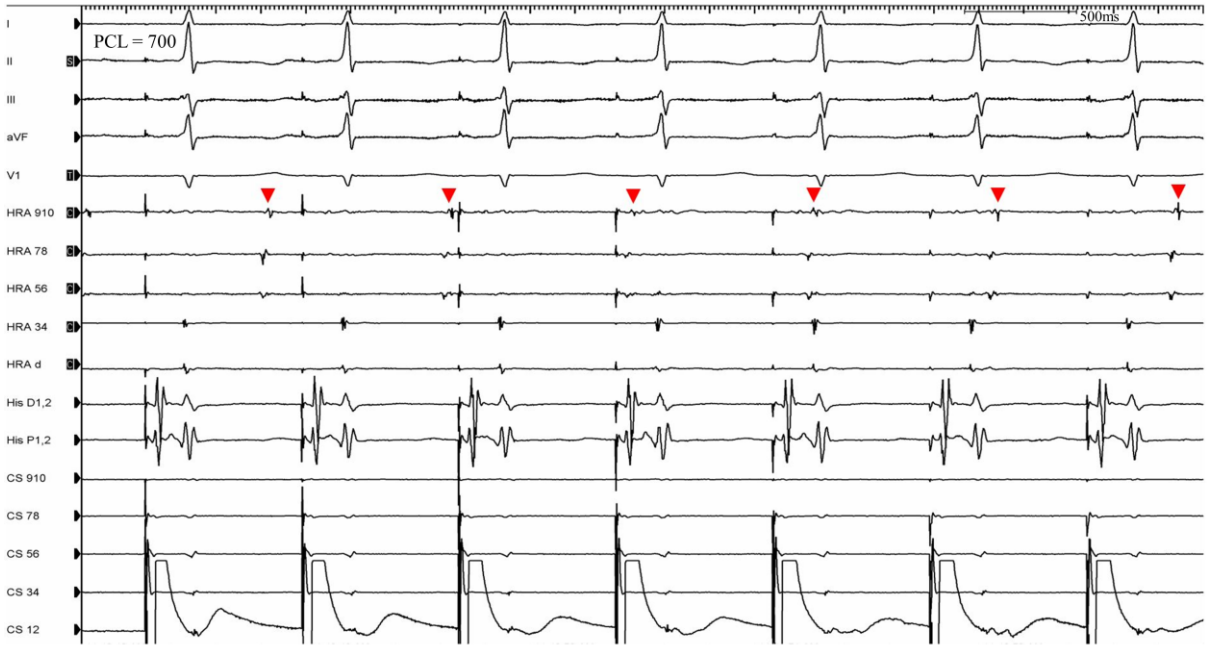


Figure S2.

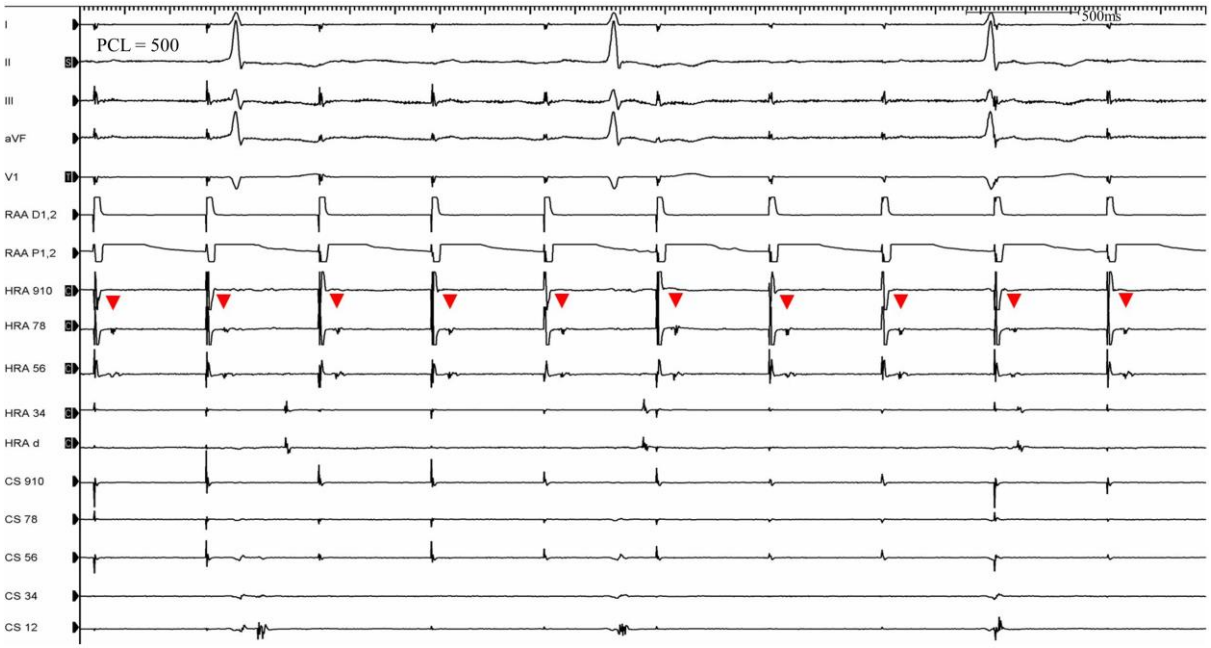
A



B


PCL = 700
500ms
I
II
III
aVF
V1
HRA 910
HRA 78
HRA 56
HRA 34
HRA d
His D1,2
His P1,2
CS 910
CS 78
CS 56
CS 34
CS 12

C


500ms
PCL = 500
I
II
III
aVF
V1
RAA D1,2
RAA P1,2
HRA 910
HRA 78
HRA 56
HRA 34
HRA d
CS 910
CS 78
CS 56
CS 34
CS 12

D

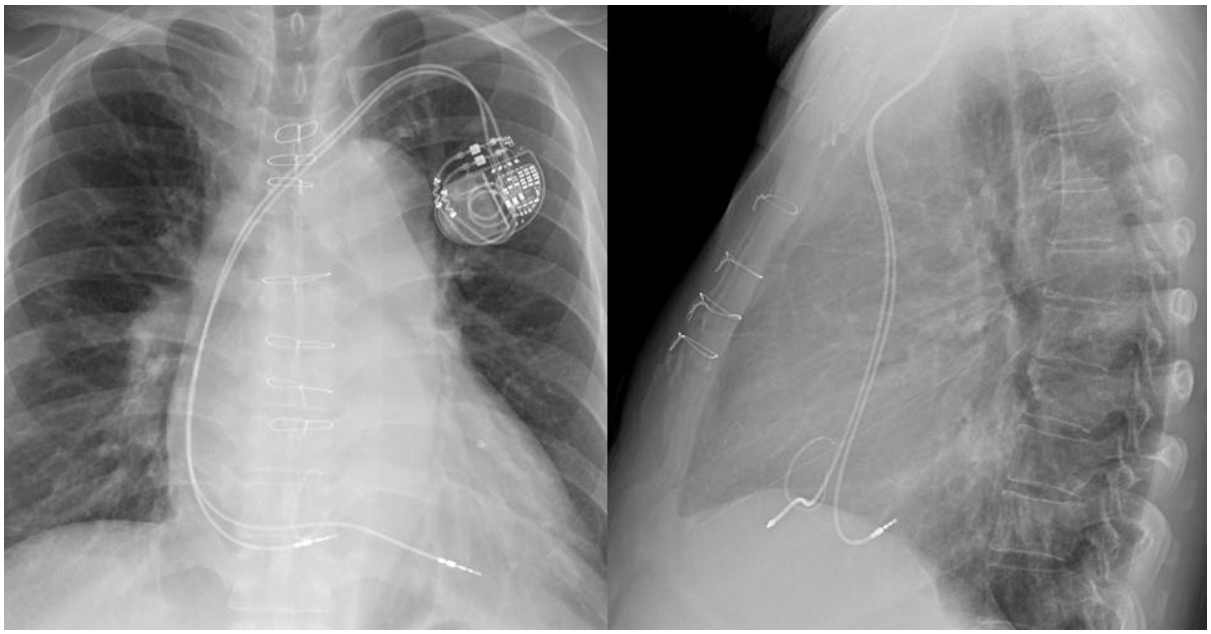
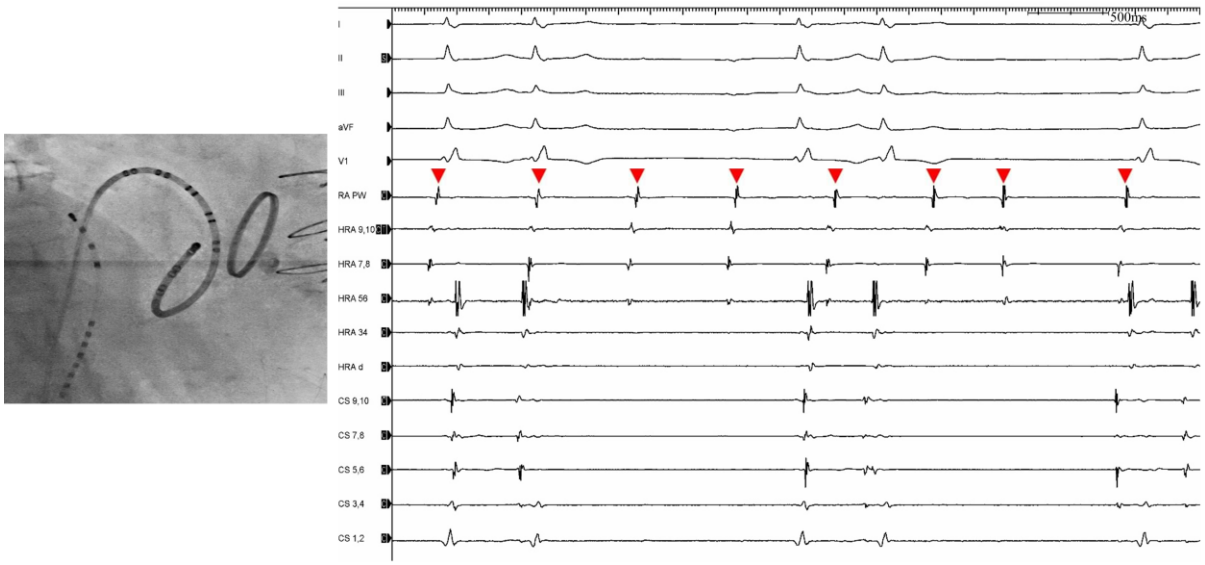


Figure S3.

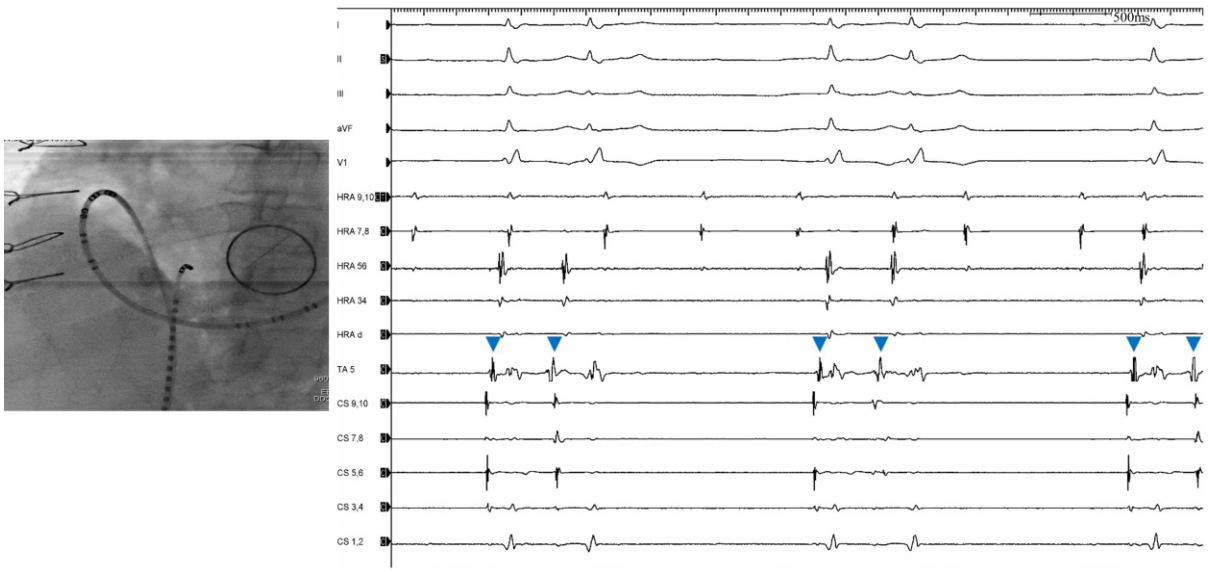
A


PCL = 400
500ms
I
II
III
aVF
V1
HRA 9,10
HRA 7,8
HRA 56
HRA 34
HRA d
His
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2

B


500ms
I
II
III
aVF
V1
RA PW
HRA 9,10
HRA 7,8
HRA 56
HRA 34
HRA d
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2

C

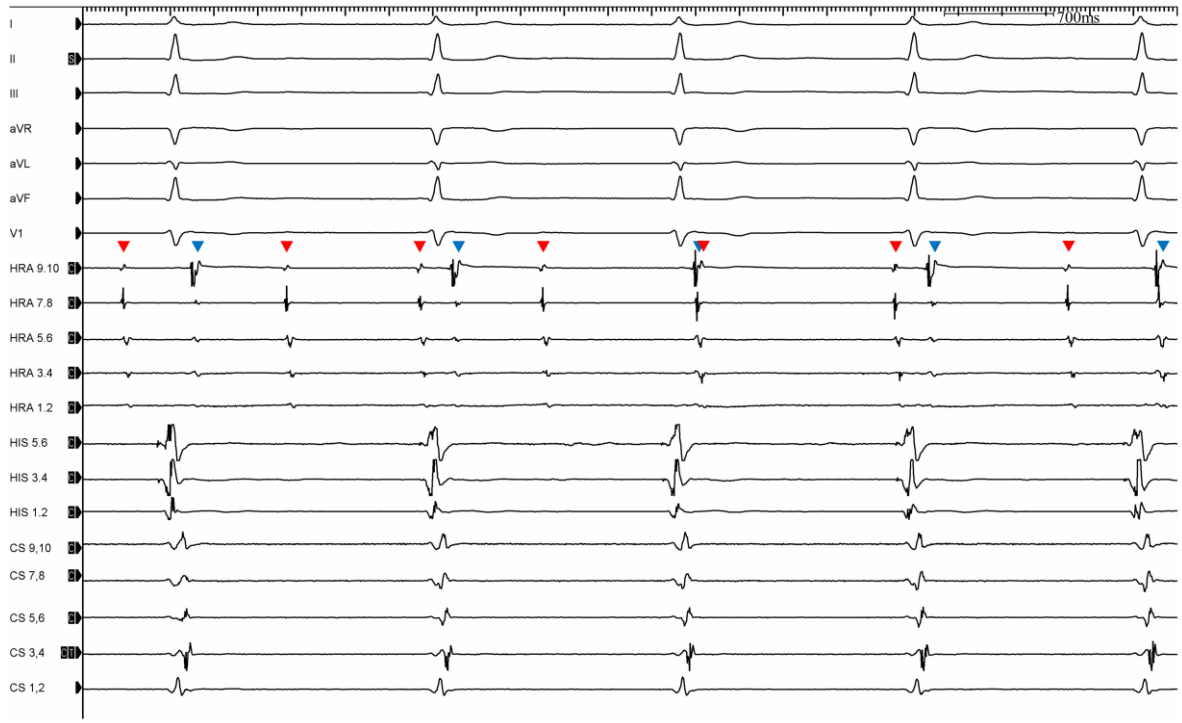

500ms
I
II
III
aVF
V1
HRA 9,10
HRA 7,8
HRA 56
HRA 34
HRA d
TA 5
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2

D

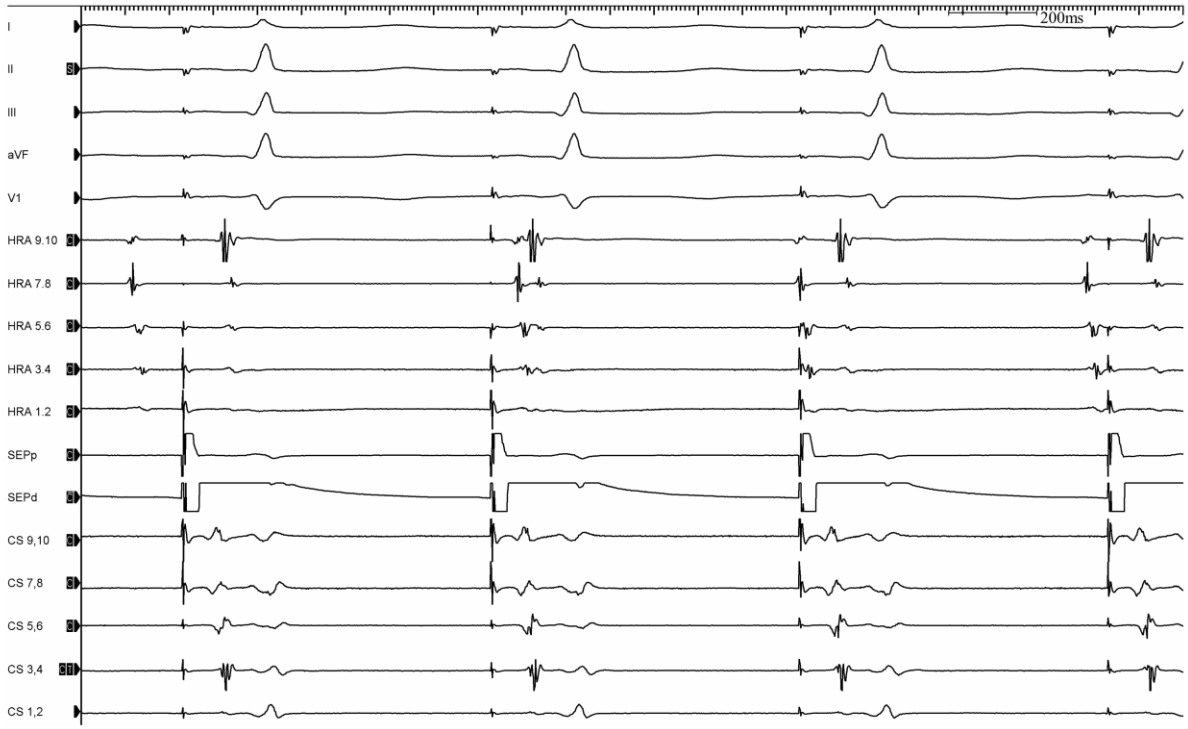

500ms
I
II
III
aVF
V1
HRA 9,10
HRA 7,8
HRA 56
HRA 34
HRA d
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2

Figure S4.

A


700ms
I
II
III
aVR
aVL
aVF
V1
HRA 9.10
HRA 7.8
HRA 5.6
HRA 3.4
HRA 1.2
HIS 5.6
HIS 3.4
HIS 1.2
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2

B


200ms
I
II
III
aVF
V1
HRA 9.10
HRA 7.8
HRA 5.6
HRA 3.4
HRA 1.2
SEPp
SEPd
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2

C

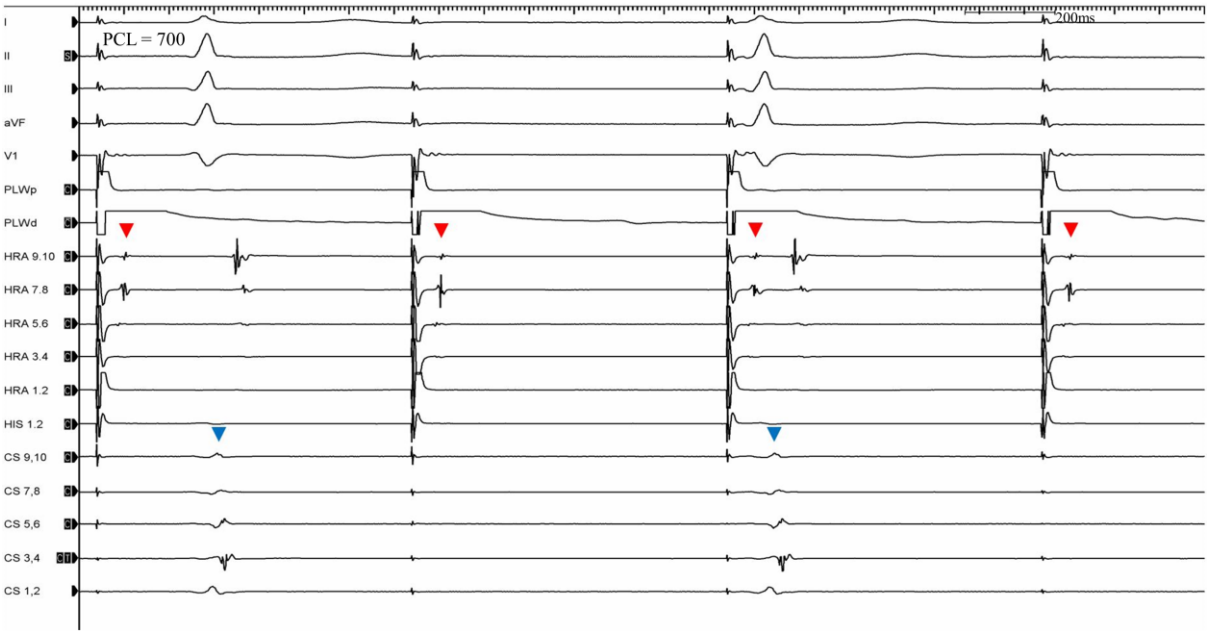
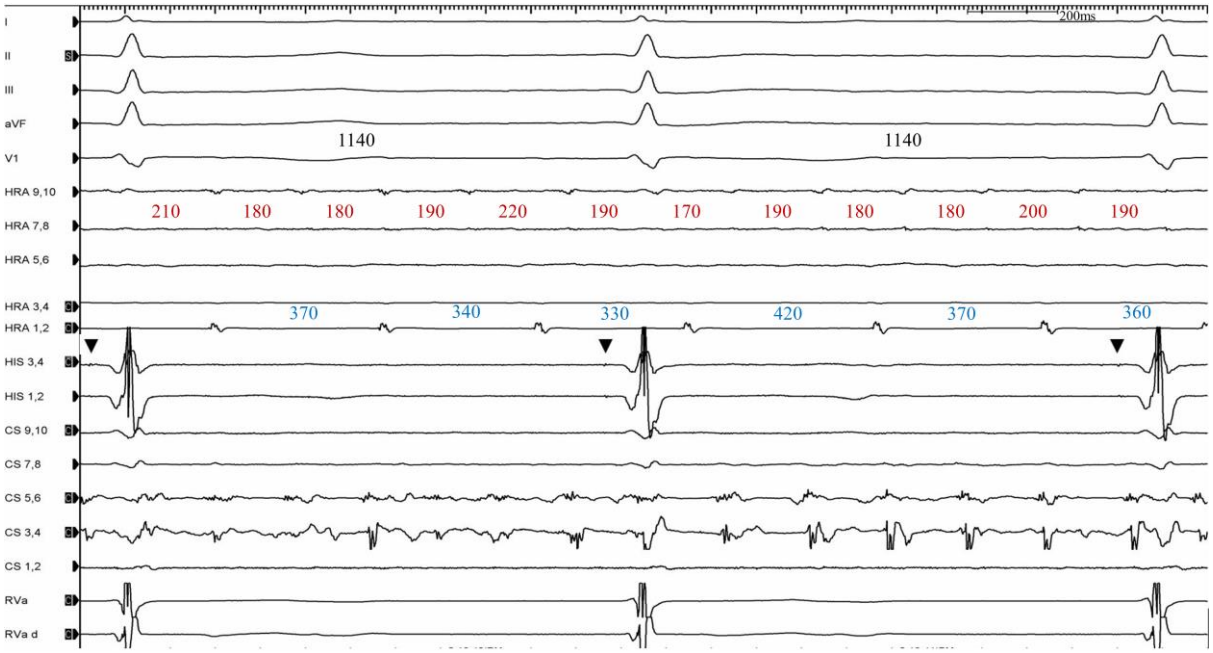

I
II
III
aVF
V1
PLWp
PLWd
HRA 9.10
HRA 7.8
HRA 5.6
HRA 3.4
HRA 1.2
HIS 1.2
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2
PCL = 700
200ms

Figure S5.

A


200ms
I
II
III
aVF
V1
HRA 9,10
HRA 7,8
HRA 5,6
HRA 3,4
HRA 1,2
HIS 3,4
HIS 1,2
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2
RVa
RVa d
1140
1140
210 180 180 190 220 190 170 190 180 180 200 190
370 340 330 420 370 360

B


1000ms
PCL = 1000
I
II
III
aVF
V1
HRA 9,10
HRA 7,8
HRA 5,6
HRA 3,4
HRA 1,2
HIS 5,6
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2
RVa d
RVa
RR 930 RR 1140 RR 780 RR 1126 RR 900 RR 1148 RR 810 RR 1140 RR 870

C

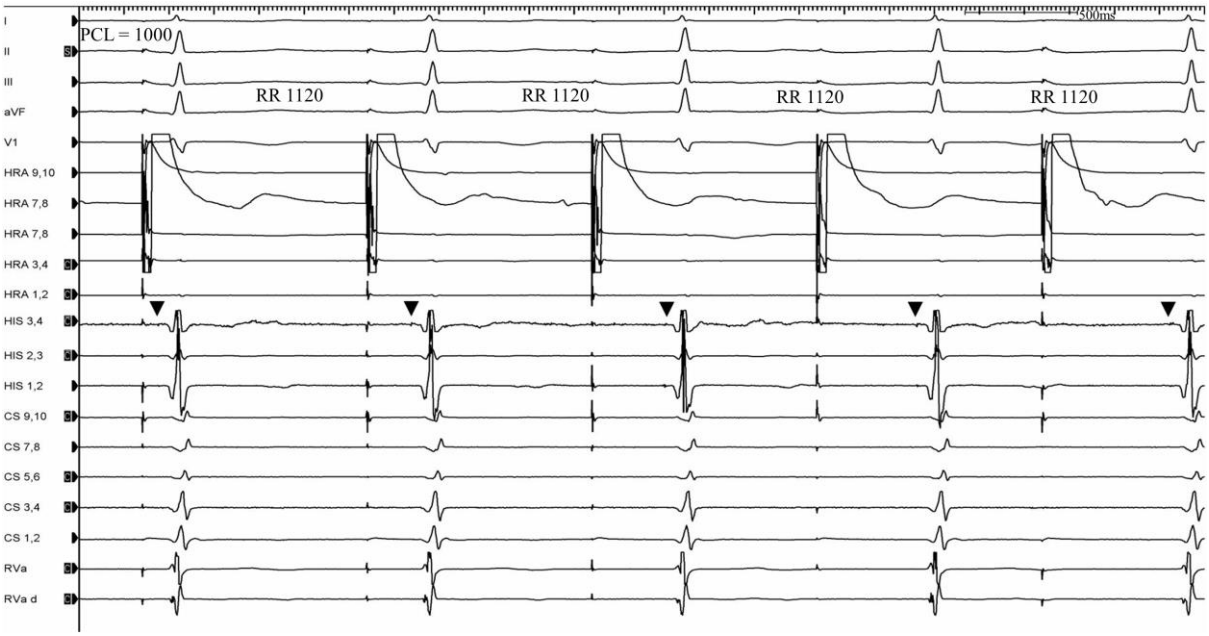
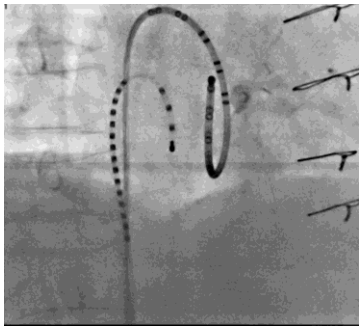
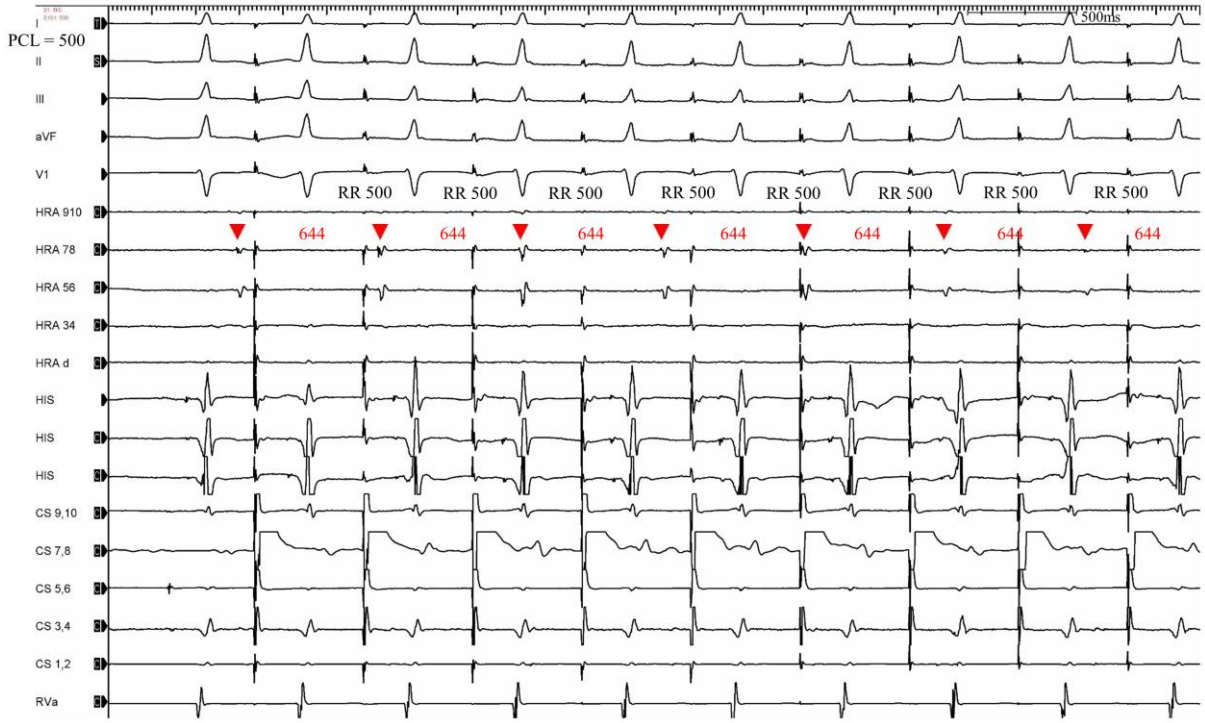

I
II
III
aVF
V1
HRA 9,10
HRA 7,8
HRA 7,8
HRA 3,4
HRA 1,2
HIS 3,4
HIS 2,3
HIS 1,2
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2
RVa
RVa d
PCL = 1000
RR 1120
RR 1120
RR 1120
RR 1120
500ms

Figure S6.

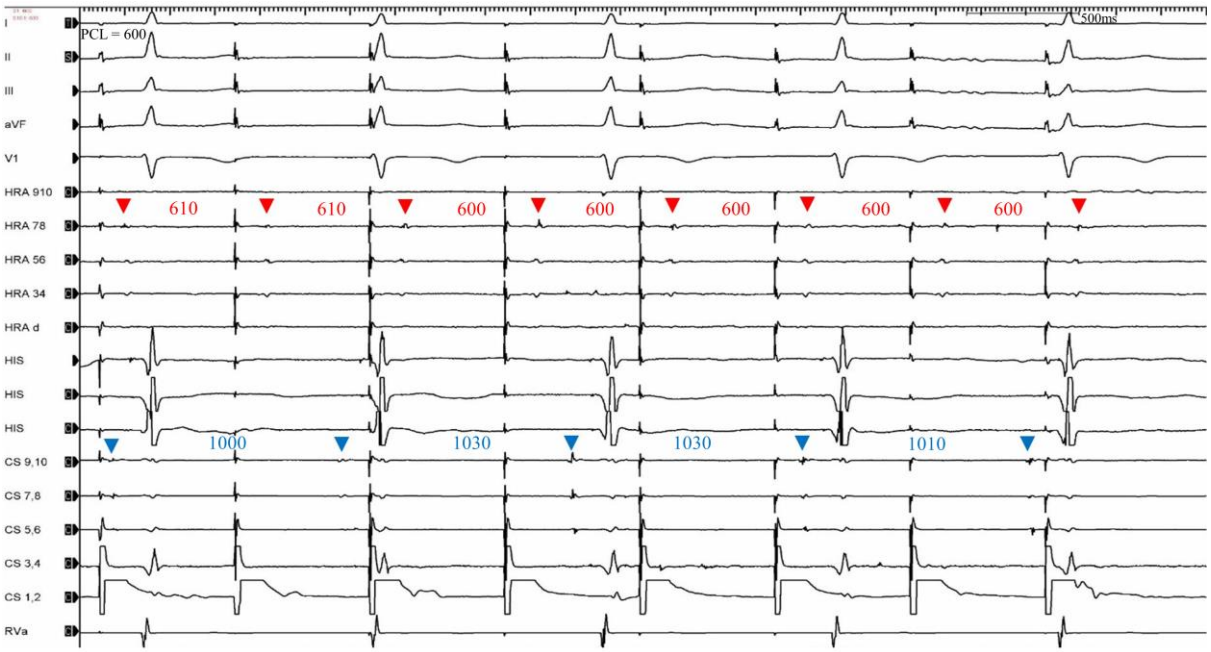
A



B


500ms
PCL = 500
I
II
III
aVF
V1
HRA 910
HRA 78
HRA 56
HRA 34
HRA d
HIS
HIS
HIS
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2
RVa
RR 500
644

C


500ms
PCL = 600
I
II
III
aVF
V1
HRA 910
HRA 78
HRA 56
HRA 34
HRA d
HIS
HIS
HIS
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2
RVa
610
610
600
600
600
600
600
1000
1030
1030
1010

D


200ms
PCL = 380
I
II
III
aVF
V1
HRA 910
HRA 78
HRA 56
HRA 34
HRA d
HIS
HIS
HIS
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2
RVa
RR 454
RR 454
RR 454
RR 454
RR 454

E

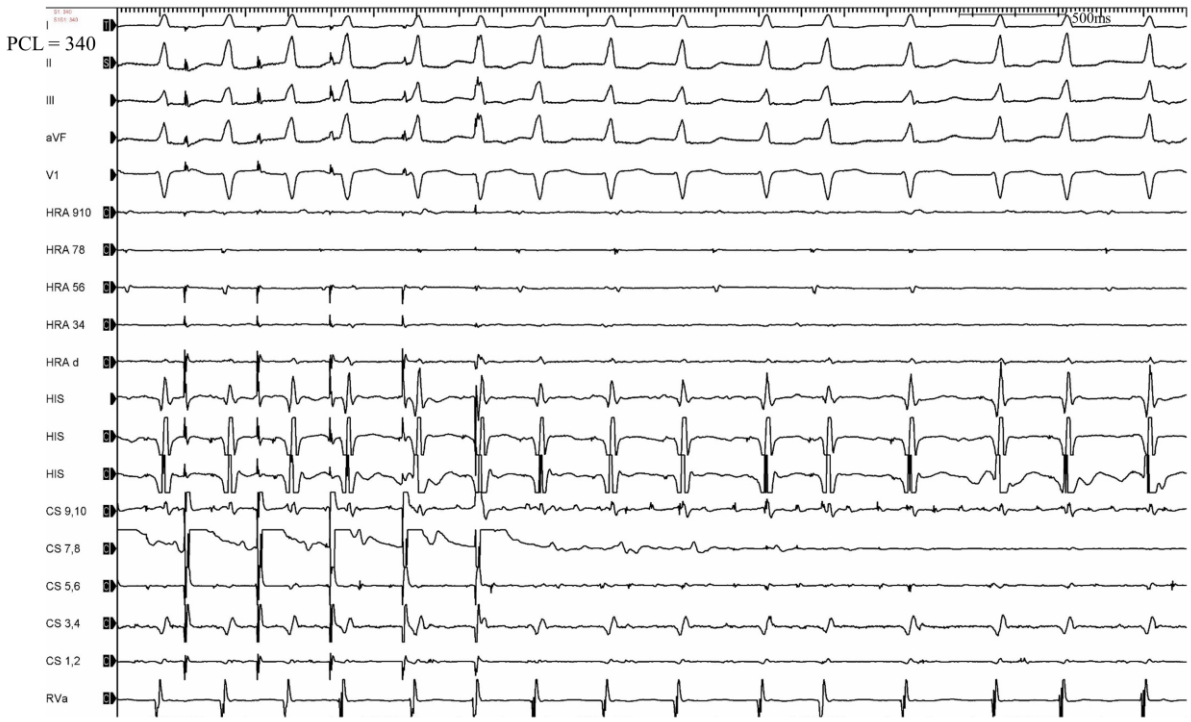
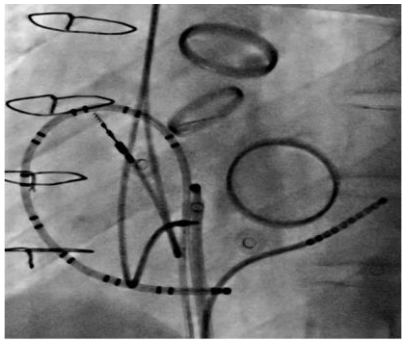
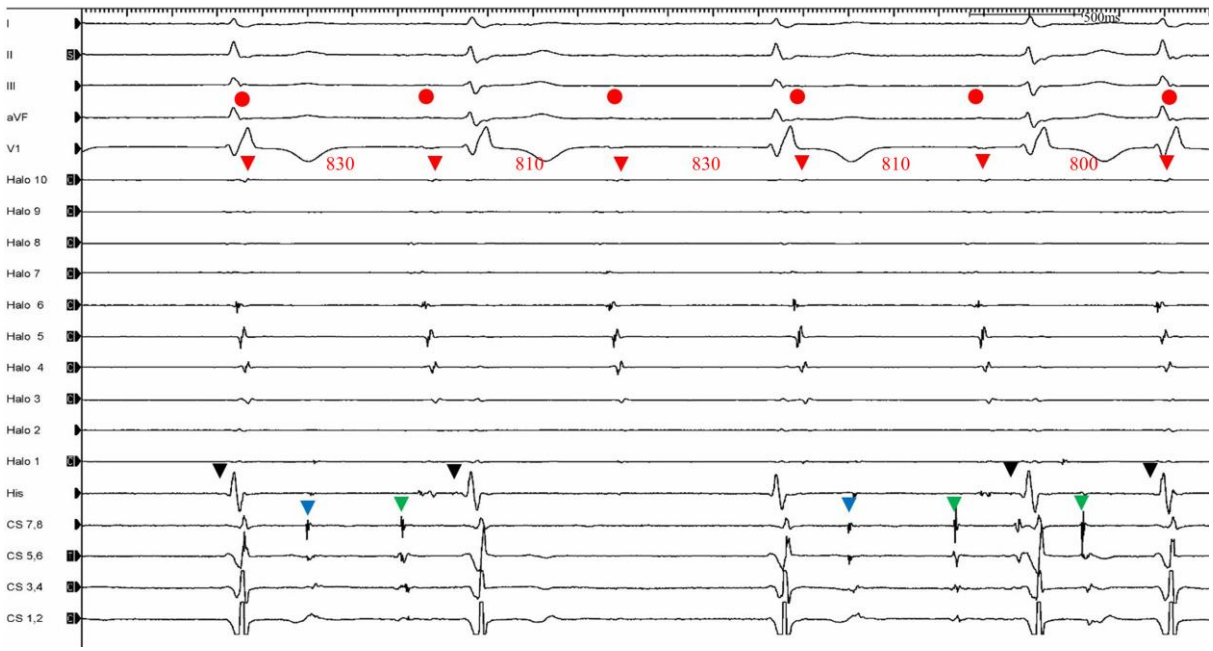

PCL = 340
500ms
I
II
III
aVF
V1
HRA 910
HRA 78
HRA 56
HRA 34
HRA d
HIS
HIS
HIS
CS 9,10
CS 7,8
CS 5,6
CS 3,4
CS 1,2
RVa

Figure S7.

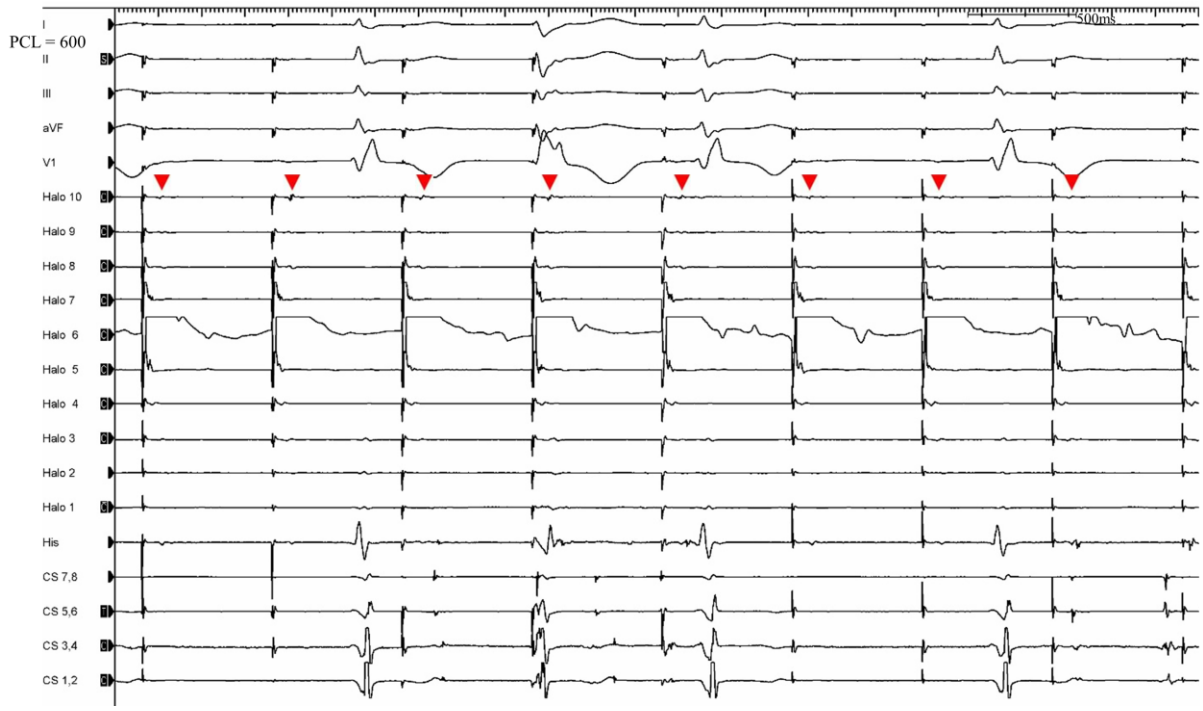
A



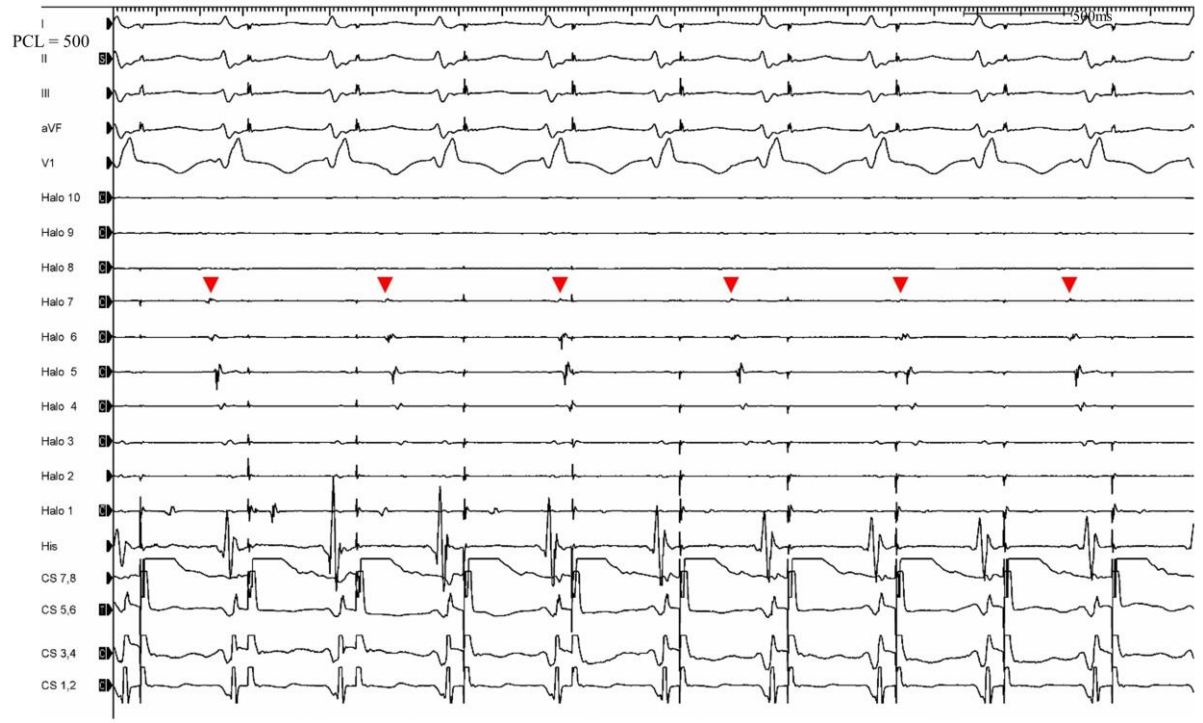
B


500ms
I
II
III
aVF
V1
Halo 10
Halo 9
Halo 8
Halo 7
Halo 6
Halo 5
Halo 4
Halo 3
Halo 2
Halo 1
His
CS 7,8
CS 5,6
CS 3,4
CS 1,2
830
810
830
810
800

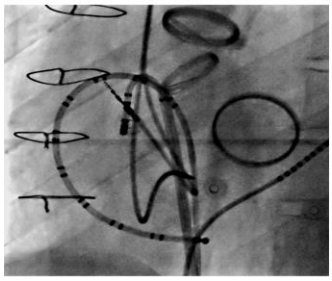
C

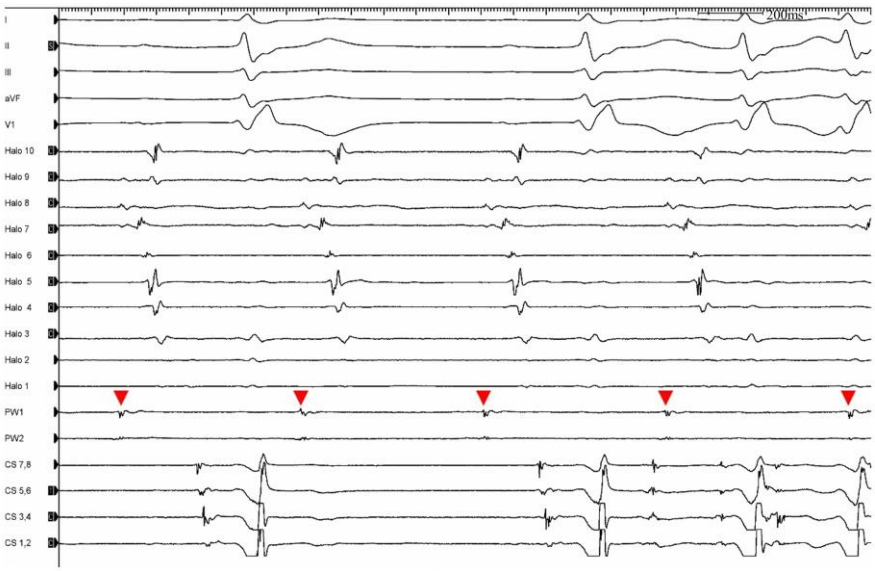

PCL = 600
500ms
I
II
III
aVF
V1
Halo 10
Halo 9
Halo 8
Halo 7
Halo 6
Halo 5
Halo 4
Halo 3
Halo 2
Halo 1
His
CS 7,8
CS 5,6
CS 3,4
CS 1,2

D

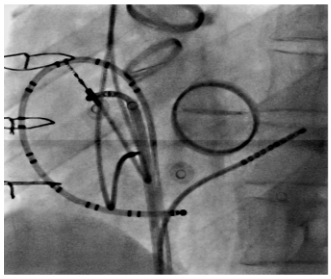

PCL = 500
500ms
I
II
III
aVF
V1
Halo 10
Halo 9
Halo 8
Halo 7
Halo 6
Halo 5
Halo 4
Halo 3
Halo 2
Halo 1
His
CS 7,8
CS 5,6
CS 3,4
CS 1,2

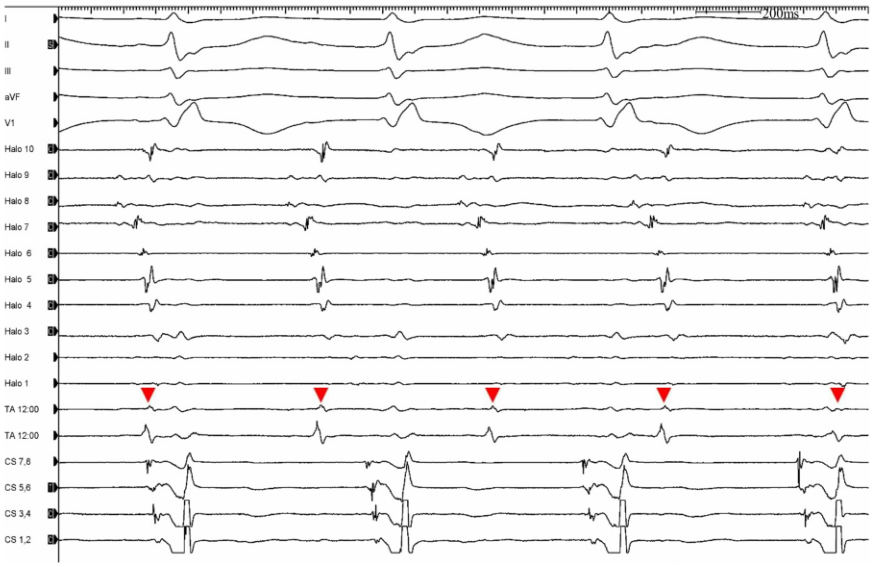
E



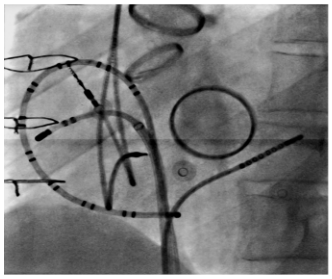

200ms
I
II
III
aVF
V1
Halo 10
Halo 9
Halo 8
Halo 7
Halo 6
Halo 5
Halo 4
Halo 3
Halo 2
Halo 1
PW1
PW2
CS 7,8
CS 5,6
CS 3,4
CS 1,2

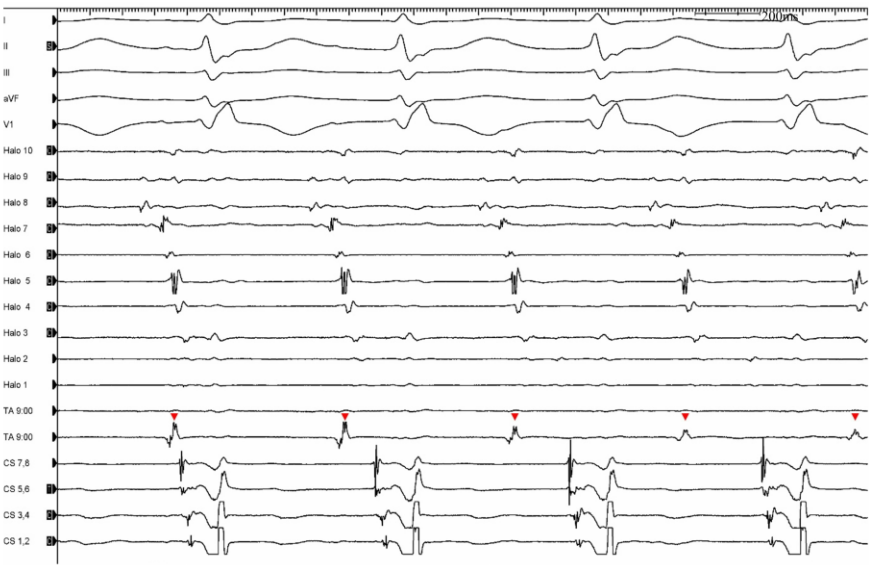
F



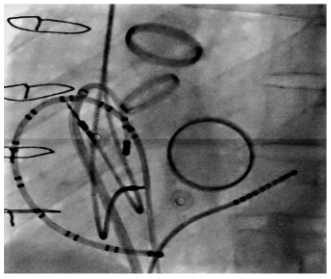

200ms
I
II
III
aVF
V1
Halo 10
Halo 9
Halo 8
Halo 7
Halo 6
Halo 5
Halo 4
Halo 3
Halo 2
Halo 1
TA 12:00
TA 12:00
CS 7,8
CS 5,6
CS 3,4
CS 1,2

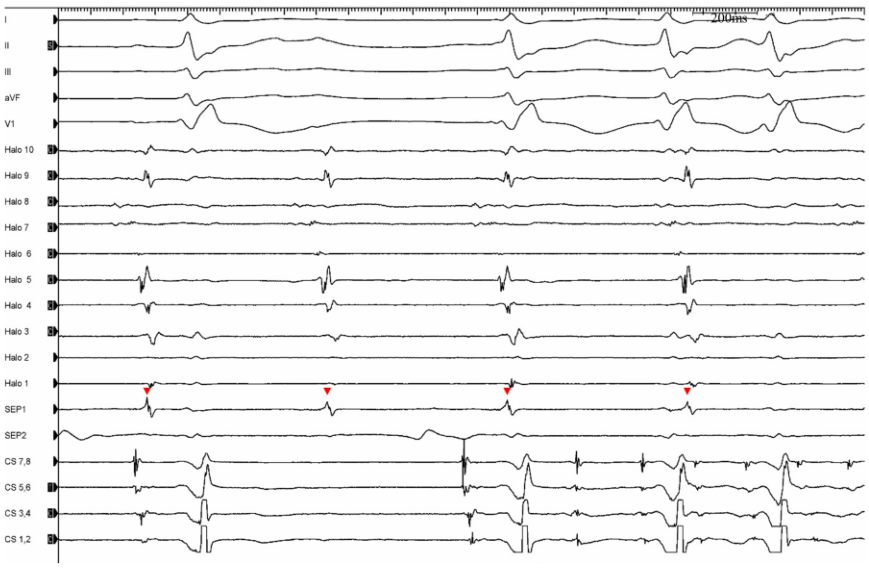
G



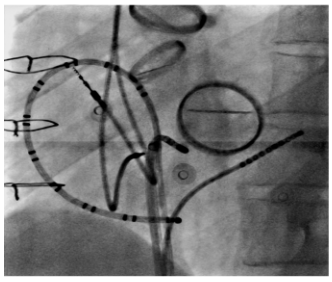

I
II
III
aVF
V1
Halo 10
Halo 9
Halo 8
Halo 7
Halo 6
Halo 5
Halo 4
Halo 3
Halo 2
Halo 1
TA 9:00
TA 9:00
CS 7,8
CS 5,6
CS 3,4
CS 1,2

H



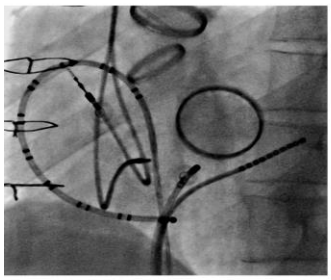

I
II
III
aVF
V1
Halo 10
Halo 9
Halo 8
Halo 7
Halo 6
Halo 5
Halo 4
Halo 3
Halo 2
Halo 1
SEP1
SEP2
CS 7,8
CS 5,6
CS 3,4
CS 1,2

I




200ms
I
II
III
aVF
V1
Halo 10
Halo 9
Halo 8
Halo 7
Halo 6
Halo 5
Halo 4
Halo 3
Halo 2
Halo 1
TA 3:00
TA 3:00
CS 7,8
CS 5,6
CS 3,4
CS 1,2

J



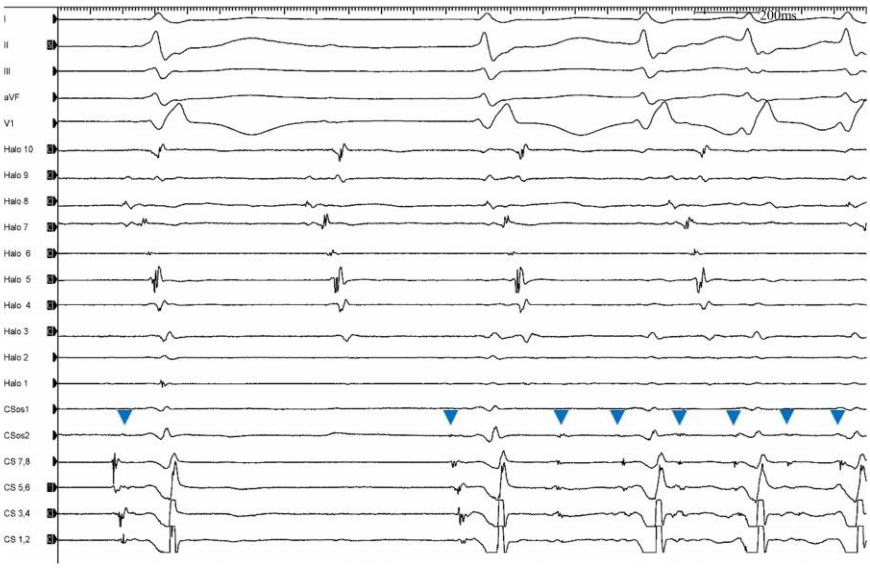
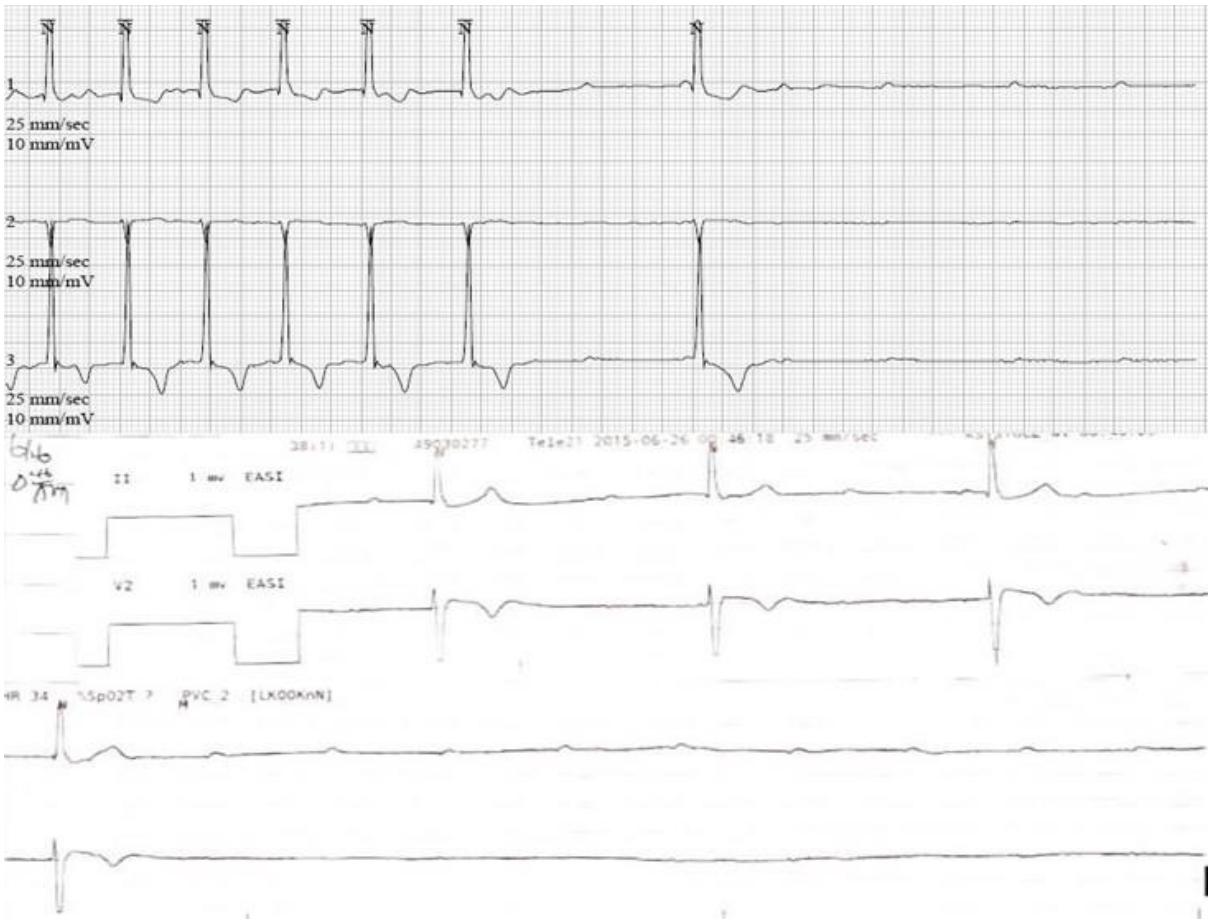

200ms
I
II
III
aVF
V1
Halo 10
Halo 9
Halo 8
Halo 7
Halo 6
Halo 5
Halo 4
Halo 3
Halo 2
Halo 1
CSos1
CSos2
CS 7,8
CS 5,6
CS 3,4
CS 1,2

Figure S8.


1
25 mm/sec
10 mm/mV
2
25 mm/sec
10 mm/mV
3
25 mm/sec
10 mm/mV
II 1 mv EASI
V2 1 mv EASI
PVC 2