Electrocardiographic analysis in a patient with dual atrioventricular nodal non-re-entrant tachycardia

Jing Chen[1], Bei Wang[2], Fan Lin[1], Ping Zuo[1], Li Lin[1], Xiao Yun Yang[1]

1 Division of Cardiology and Department of Internal Medicine, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan 430030, China.

2 Department of Rheumatology and Immunology, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, Wuhan, China.

Corresponding authors and Lead contacts:

Xiao Yun Yang

Division of Cardiology and Department of Internal Medicine, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, 1095# Jiefang Ave., Wuhan 430030, China

Email: yangxiaoyun321@126.com

Keywords

1: 2 AV conduction; Slow pathway; DAVNNT; Holter; Ablation

Abstract

1:2 atrioventricular (AV) conduction is characterized by one atrial activation antegrade conduction down fast and slow pathways, which results in two ventricular activations. This phenomenon also referred to as a "double fire". When this phenomenon repeats rapidity, dual atrioventricular node non-re-entrant tachycardia (DAVNNT) occurs. We report the case of irregular QRS complexes tachycardia with a comprehensive record of this phenomenon including, routine electrocardiogram, Holter recordings, and intracardiac electrophysiological study (EPS). In conclusion, through analysis of the ECG and intracardiac recording during tachycardia, we presume that the most likely electrophysiological explanation of our case is the "double ventricular response to a single sinus beat".

Case presentation

A 56-years-old male patient was referred to our Cardiology Department for intermittent palpitation and discomfort. Symptoms started 6 years before but worsened over the past months. The echocardiographic examination revealed arrhythmia and ruled out structural heart disease. He presented to another hospital before and was diagnosed with atrial fibrillation by ECG in Figure 1A. On admission, the patient underwent Holter examination and electrophysiological study. What is the likely mechanism of the tachycardia in this case?

Discussion

The baseline ECG shows intermittent P-waves (P_1, P_4, P_9, P_{12}) linked to the first of the two QRS complexes with a constant PR interval of 220 milliseconds (ms). (Figure 1A). By a beat-to-beat morphological analysis of T waves, hidden P waves (P_2, P_5, P_{13}) are subsequently identified (Figure 1A). Subsequently, regular PP (P_1-P_{13}) intervals are identified with a cycle length of 760 ms, and rule out the possibility diagnose of atrial fibrillation. Regular P waves are upright in the inferior leads and inverted in lead aVR suggesting they are sinus P waves. Furthermore, PR interval prolongation (440 ms) after the 2nd QRS complexes (R_2, R_6, R_{12}, R_{16}) can be interpreted either by the concealed retrograde conduction to the AV node by ventricular or junctional extrasystoles which prolonged the ensuing AV node conduction, or by slow AV nodal pathway conduction (Figure 1A). Irregular wide QRS complexes may occur at refractory of right bundle branch. Therefore, the possible differential diagnosis of Figure 1A include 1) sinus rhythm with ventricular extrasystoles; 2) sinus with junctional extrasystoles; and 3) sinus rhythm atrioventricular (AV) nodal nonreentrant tachycardia.

By a beat-to-beat analysis of PR intervals, during sinus rhythm (marked by P_2, P_7, P_{10}), atrial activation antegrade conduct through AV node to create QRS complexes (marked by R_3, R_9, R_{13}) with very long PR intervals (440 ms). It make likely a manifestation of slow-pathway-only conduction. The ladder diagram in Figure 1A reveales the hypothesis of a double ventricular response to a single sinus beat. ECG at admission (Figure 1B) shows sinus rhythm with PR interval 440 ms, and occasional Mobitz I second-degree AV block. It further likely a manifestation of slow-pathway-only conduction. Sinus origin of P wave, two distinct PR intervals (220 ms and 440 ms, respectively) and the presence of anterograde conduction only down the slow pathway, make the diagnose of dual ventricular response through dual AV nodal pathways most likely.

Series of data are obtained from automatic Holter ECG analysis system. As shown in Figure 2, data are shown including Lorenz-RR interval scatter plot (Figure 2A), 24-h tachogram (RR intervals over time) (Figure 2B), 1-h tachogram (RR intervals over time) (Figure 2C), 1-h P waves of chromatograms (Figure 2D) and ECG tracings (Figure 2E). The Lorenz-RR plot displays a double side lobe (DSL) pattern type containing 3 islets. The central part (1) of the DSL shape reflects normal sinus rhythm, while the left (2) and right (3) side lobe reflects resembling very frequent premature depolarizations (Figure 2A). The 24-h RR intervals over time showed the distribution of 3-4 layers, and the dominant rhythm was in the uppermost layer, and the lower 2-3 layers are the RR interval bands during tachycardia (Figure 2B). Furthermore, the 1-h RR intervals over time was an example which associated with islet marked 1. The 1-h RR intervals over time showed an abnormal RR interval with 3 distinct layers (Figure 2C). The DSL shape of Lorenz plot and the distribution of 3-4 layers of 24-h and 1-h RR intervals over time are highly specifically linked to frequent atrial premature beats[1].

Furthermore, Figure 2D showed example of 1-h P-wave chromatogram associated with islet marked 2. P-wave chromatogram is a novel method for automatic detecting atrial fibrillation. During sinus rhythm, the positions of P waves represented by black band, whereas positions of QRS complexes represented by orange band. The distance between the two bands represented the PR intervals. P-wave chromatogram showed sinus rhythm with identical PR intervals whereas atrial fibrillation with chaotic PR intervals. Therefore, P-wave chromatogram had an excellent sensitivity and specificity for the presence of atrial fibrillation. The fixed PR intervals were specific for normal sinus rhythm, while variable PR intervals suggested the presence of one or more tachyarrhythmias. It helped us to improve diagnostic efficacy regarding arrhythmia detection and diagnosis. In our case, Figure 2D showed variable PR intervals associated with islet marked 2 by P-wave chromatogram and suggested the presence of one or more tachyarrhythmias.

The ECG tracing is an example of tachyarrhythmias substrate associated with islet marked 2 (Figure 2E). ECG tracing shows irregular QRS complex tachycardia with P waves linked to two QRS complexes. A differential diagnose of dual ventricular response through dual AV nodal pathways, junctional extrasystoles in bigeminy or (less likely) atrial tachycardia is made.

The patient then underwent the electrophysiology study (EPS), multipolar catheters are placed in the coronary sinus and right ventricular region. Atrial potentials are recorded by catheters in the coronary sinus. His potentials and ventricular potentials are simultaneously recorded by the catheters placed in the right ventricular septum[2]. Purkinje potentials are recorded before the onset of the QRS. Retrograde conduction was absent during right ventricular pacing. Baseline heart rate is sinus rhythm with a cycle length of 827 ms, and AH and HV intervals were 106 ms and 31 ms, respectively (Figure 3A). Subsequently, tachycardia spontaneously occurred. Atrial potentials recorded by catheters in the coronary sinus is regularly at a cycle length of 886 ms. His potentials and ventricular potentials simultaneously recorded by catheters in the right ventricular septum showed double ventricular response with a pattern $A\text{-}H_1\text{-}V_1\text{-}H_2\text{-}V_2$. The AH_1 and AH_2 interval were 100 ms and 615 ms, and H_1V and H_2V intervals were constant 31 ms (Figure 3B). Junctional extrasystoles may double the ventricular rate, however, they typically had a less predictable coupling interval to the receding QRS complex or His potential[3,4]. Because of the fixed interval between His and ventricular activation, junctional extrasystoles was unlikely. Furthermore, surface lead I, II and V_1 ECG showed right bundle branch block in the 2^{nd} wide QRS complexes of the preceding atrial excitation. The increased incidence of functional bundle branch block in the ventricular rate due to dual AV nodal non-reentrant tachycardia is often observed, but it is not a prerequisite[5]. This finding also favored the diagnosis of AV nodal non-reentrant tachycardia. Figure 3C shows similarly 1:2 anterograde AVN conduction, whereas the AH_1 interval is very long at 378 ms. Antegrade conduction down the fast pathway and slow pathway showed variable AH intervals may due to fluctuations in AV nodal conduction velocity[6].

After ablation in the slow pathway, the dual ventricular response was disappeared. After observation for 30 min, CS pacing showed no evidence of dual AV node physiology and inducible of tachycardia. RV pacing showed no VA conduction even with an ISP drip. The patient was reexamined with Holter after radiofrequency catheter ablation, and the Lorenz-RR interval scatter plot and RR intervals over time confirmed the disappearance of 1:2 AV conduction.

Conclusions

DAVNNT is an uncommon arrhythmia and associated with a reversible tachycardia-induced cardiomyopathy[7]. Dual AV node physiology provide the substrate for a sinus beat resulted double ventricular response (Figure 3D). It is difficult to discriminate between DAVNNT and more common arrhythmias by patient characteristics and clinical presentation.[4]. Our case provides a comprehensive analysis of this phenomenon.

Routine ECG (Figure 1A-B) revealed sinus origin of P wave, two constant PR intervals (220 ms and 440 ms, respectively) and the hypothesis of presence of anterograde conduction only down the slow pathway. Tachycardia was revealed by the long-term recording from Holter. The DSL shape of Lorenz plot and the distribution of 3-4 layers of 24-h and 1-h RR intervals over time are highly specifically linked to frequent atrial premature beats. Variable PR intervals associated with islet marked 2 by P-wave chromatogram and suggested the presence of one or more tachyarrhythmias. Although junctional extrasystoles in bigeminy or (less likely) atrial tachycardia are not ruled out by ECG tracing in Figure 2E, ECG tracings associated with islet marked 1 (data were not shown) showed occasional Mobitz I second-degree AV block. It also likely manifests the presence of slow-pathway-only conduction.

In Figure 3B, we cannot completely rule out the diagnose of a parasystole with a fixed junctional rhythm and the presence of variable AH intervals. And it was reported that junctional tachycardia has also been eliminated after ablation near the typical location of the slow pathway region[8]. However, based on the thorough analysis of routine ECG, Holter and EPS, as of our case, the diagnose is suggested by DAVNNT. Therefore, thorough analysis of the ECG and intracardiac recording during tachycardia is key for the differential diagnose.

Figure legends

Figure 1. Twelve lead routine ECG. (A) Baseline ECG and corresponding schematic ladder diagrams with the hypothesis of a double ventricular response to a single sinus beat. Two antegrade conduction AV pathways are indicated by *straight lines* (fast pathway) and *dotted lines* (slow pathway). (B) ECG at admission.

Figure 2. Data of the patient's automatic Holter-ECG analysis. (A) Lorenz plot of 24-h RR intervals. (B) 24h RR intervals over time. (C) Example of 1h t-RR intervals associated with islet marked 2. (D) Example of 1h P waves of chromatogram associated with islet marked 2. (E) Example of ECG tracing associated with islet marked 2.

Figure 3. Intracardiac tracings from electrophysiology study. (A) Baseline rhythm is sinus at a cycle length of 827 ms, and AH and HV intervals were 106 ms and 31 ms, respectively (paper speed at 100 mm/s). (B) Intracardiac tracings show 1:2 AV conduction with a pattern A-H_1-V_1-H_2-V_2. The AH_1 and AH_2 interval measured 100 ms and 615 ms, and H_1V and H_2V intervals were constant 31 ms (paper speed at 50 mm/s). The ladder gram below showed the proposed mechanism for the tachycardia. Two antegrade conduction AV pathways are indicated by *straight lines* (fast pathway) and *dotted lines* (slow pathway). (C) Intracardiac tracing reveal 1:2 AV conduction with a pattern A-H_1-V_1-H_2-V_2. The AH_1 and AH_2 interval measured 378 ms and 828 ms, and H_1V and H_2V intervals were constant 31 ms (paper speed at 100 mm/s). (D) Schematic diagram of the mechanism of DAVNNT. AH, interval between the right atrium and His bundle. HV, interval between the His bundle area and ventricle. CS, recordings from catheter positioned in coronary sinus (CS 1–2 distal most and CS 9–10 at CS os). RV, recordings from catheter positioned in right ventricle.

Conflict of interests

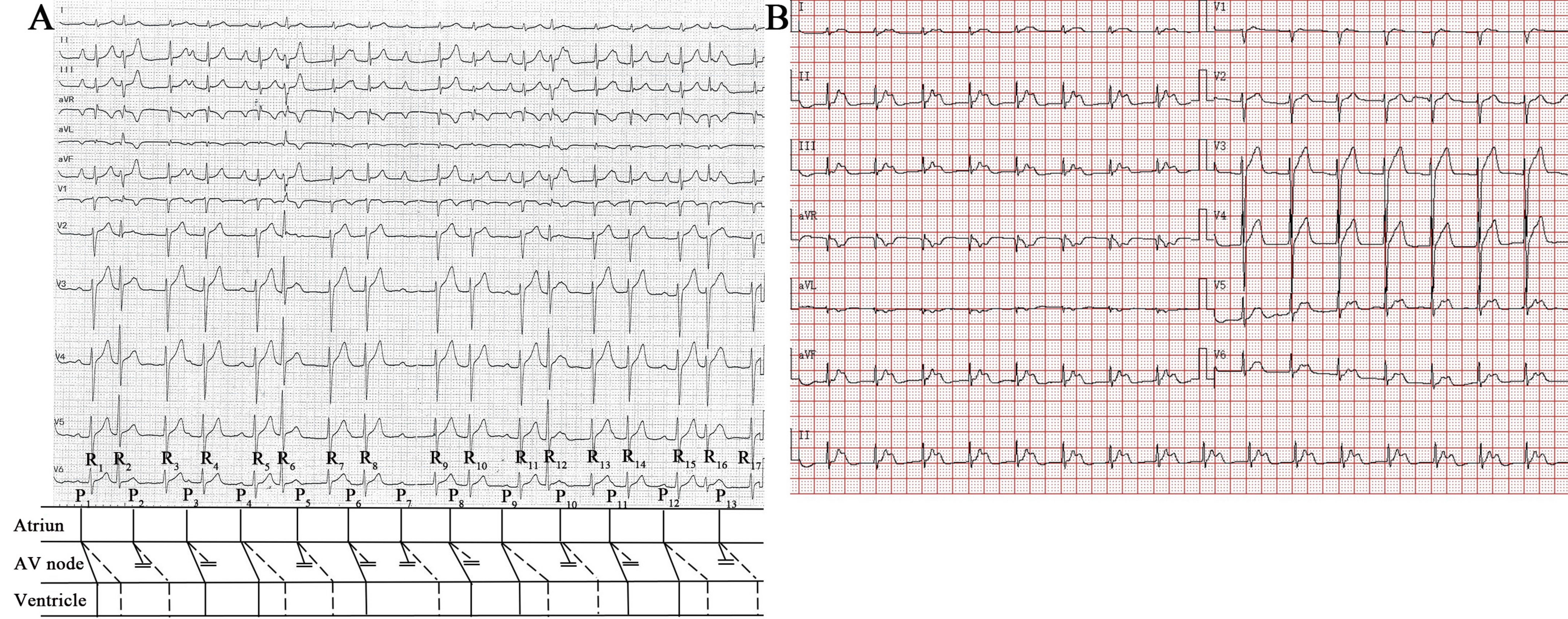
The authors declare no conflicts of interest. We confirm that the manuscript has been read and approved by all named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

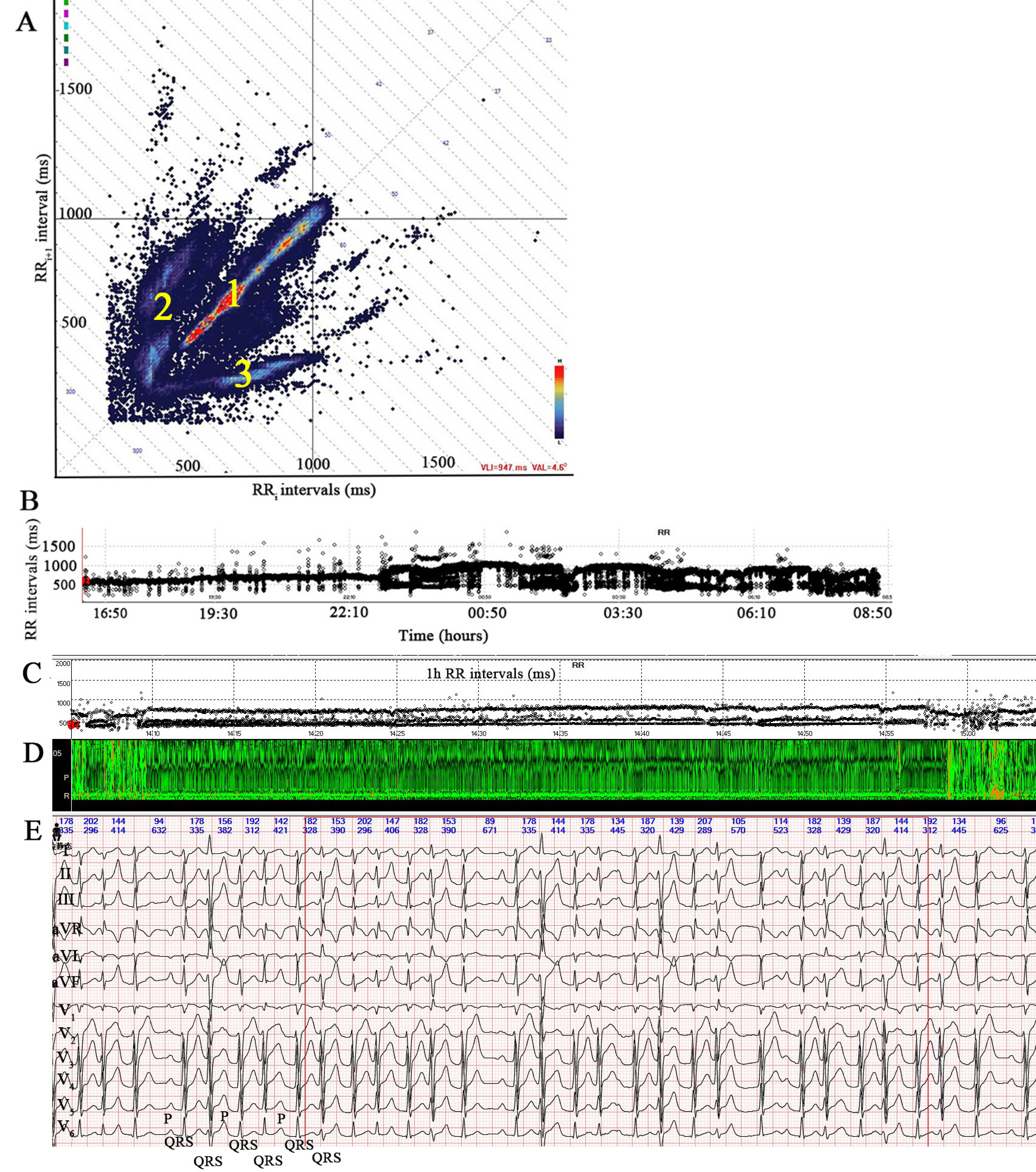
Sources of Funding

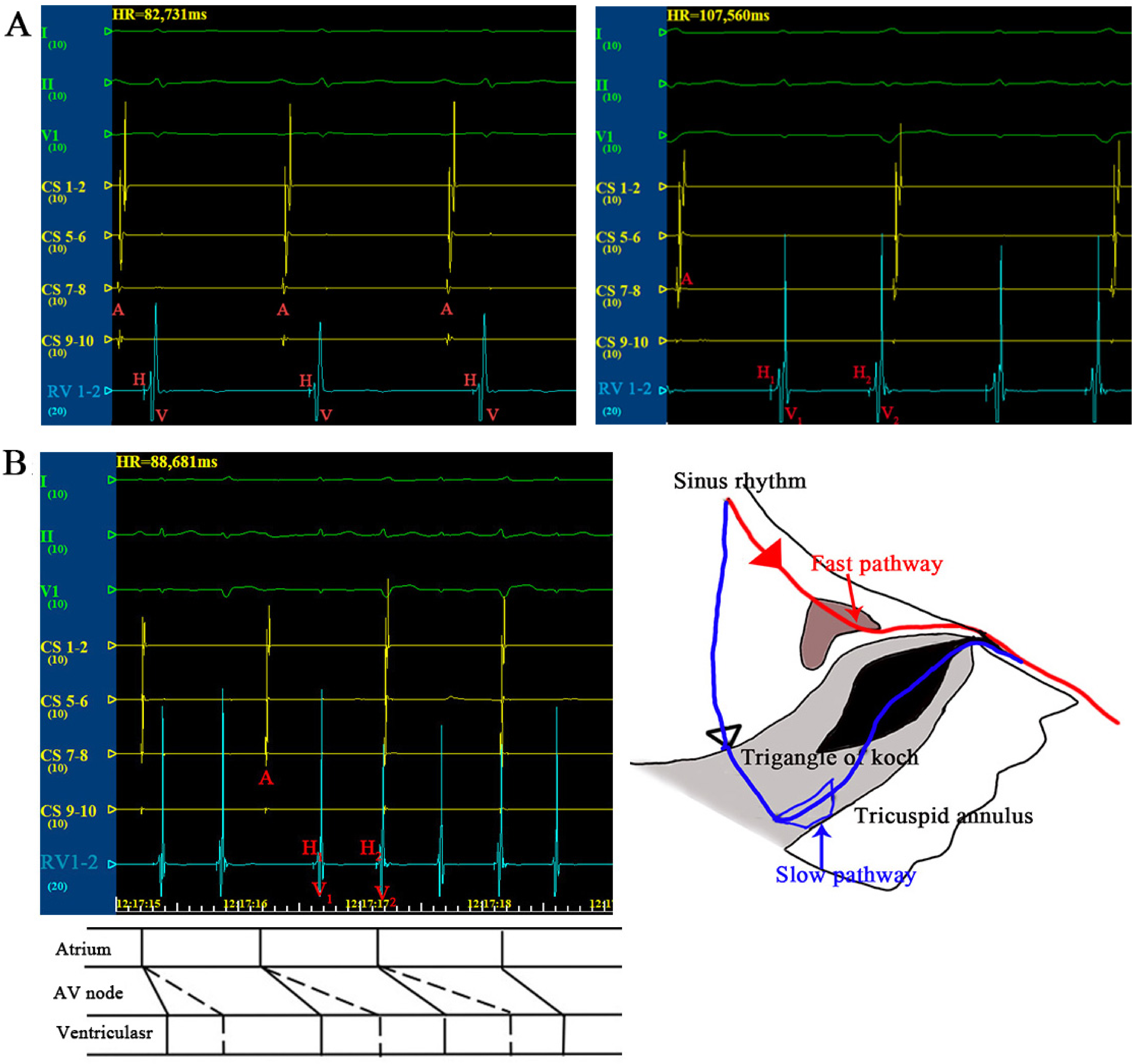
This work was supported by grant from the National Natural Science Foundation of China [81700333 to JC and 81900363 to BW].

References

1. Karey E, Pan S, Morris AN, Bruun DA, Lein PJ, Chen CY. The Use of Percent Change in RR Interval for Data Exclusion in Analyzing 24-h Time Domain Heart Rate Variability in Rodents. *Front Physiol.* 2019;10:693.
2. Nogami A. Mapping and ablating ventricular premature contractions that trigger ventricular fibrillation: trigger elimination and substrate modification. *J Cardiovasc Electrophysiol.* 2015;26(1):110-115.
3. Wang NC. Dual atrioventricular nodal nonreentrant tachycardia: a systematic review. *Pacing Clin Electrophysiol.* 2011;34(12):1671-1681.
4. Peiker C, Pott C, Eckardt L, et al. Dual atrioventricular nodal non-re-entrant tachycardia. *Europace.* 2016;18(3):332-339.
5. Chen X, Liu Y, Zhan X, et al. Irregular complex tachycardia in a 42-year-old man: What is the mechanism? *Pacing Clin Electrophysiol.* 2019;42(1):96-100.
6. Amasyali B, Kilic A. Dual atrioventricular nodal nonreentrant tachycardia: the rarest aspect of the structure causing the most frequent PSVT. *Int J Cardiol.* 2014;173(3):550.
7. Gonzalez-Torrecilla E, Avila-Alonso P. Successful cryoablation of dual atrioventricular nodal nonreentrant tachycardia: First reported cases. *Pacing Clin Electrophysiol.* 2019;42(12):1597-1600.
8. Massumi R, Shehata M. Doubling of the ventricular rate by interpolated junctional extrasystoles resembling supraventricular tachycardia. *Pacing Clin Electrophysiol.* 2010;33(8):945-949.


A
B
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
R1 R2 R3 R4 R5 R6 R7 R8 R9 R10 R11 R12 R13 R14 R15 R16 R17
P1 P2 P3 P4 P5 P6 P7 P8 P9 P10 P11 P12 P13
Atriun
AV node
Ventricle


A
1500
1000
500
1
2
3
VLI=947 ms VAL=4.6°
RR$_{i+1}$ interval (ms)
RR$_i$ intervals (ms)
B
RR intervals (ms)
RR
1500
1000
500
16:50
19:30
22:10
00:50
03:30
06:10
08:50
Time (hours)
C
1h RR intervals (ms)
RR
2000
1500
1000
500
D
E
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
P
QRS



A
HR=82,731ms
I (10)
II (10)
V1 (10)
CS 1-2 (10)
CS 5-6 (10)
CS 7-8 (10)
CS 9-10 (10)
RV 1-2 (20)
A
H
V
HR=107,560ms
H1
V1
H2
V2
B
HR=88,681ms
RV1-2 (20)
12:17:15
12:17:16
12:17:17
12:17:18
Atrium
AV node
Ventriculasr
Sinus rhythm
Fast pathway
Trigangle of koch
Tricuspid annulus
Slow pathway