Electrocardiogram in the Athlete

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Pre-participation screening can prevent sudden cardiac death in the athletes

- **Medical history:**

➢ **Personal history.**

➢ **Family history**

➢ **Physical examination**

- **ECG changes that would be considered abnormal in the untrained population may develop in trained athletes as a physiologic and benign consequence of the heart's adaptation to exercise.**

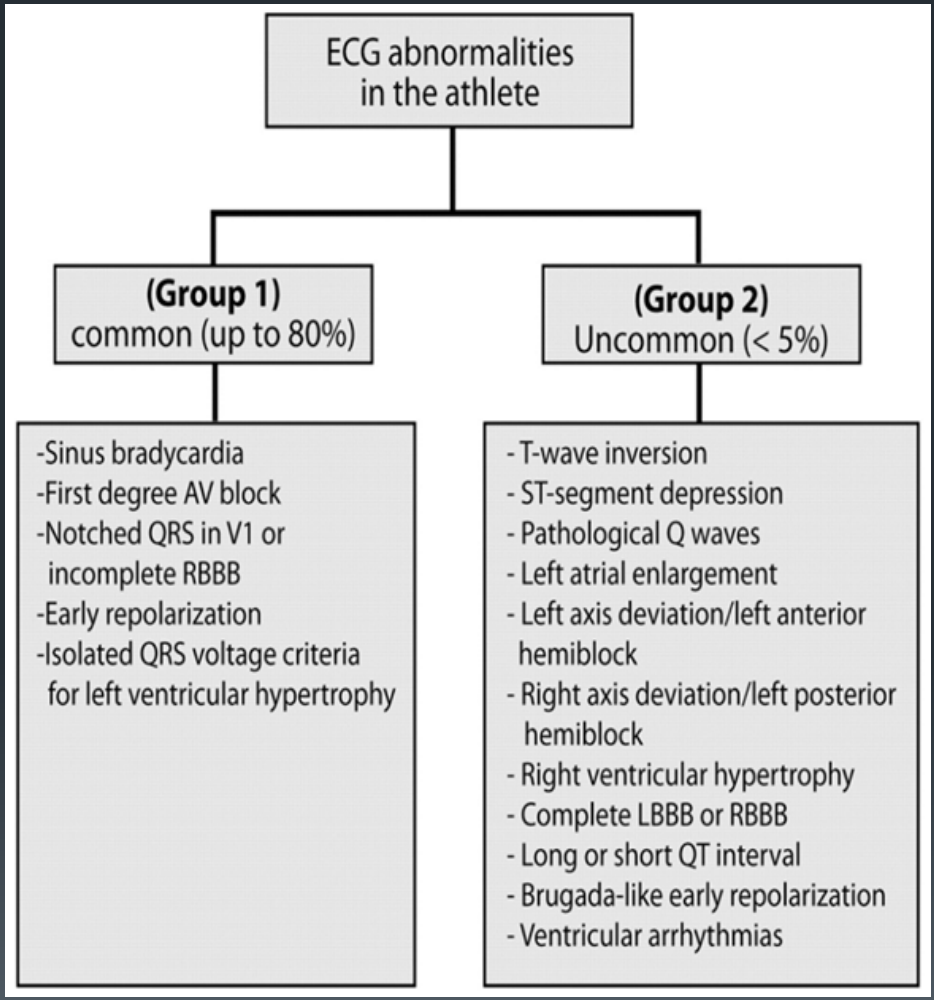
Italian program

- Young competitive athletes aged 12 to 35 years are included.
- 2 consecutive screening periods (1982-1992and1993-2004) in Italian program. The number of competitive athletes aged 12 to 35 years in the Veneto region from 1982 to 2004 was 42 386 athletes

Interpretation of ECG in athlete's

- **12-lead ECG in the athlete: physiological versus pathological abnormalities**. Review. Br J Sports Med 2009. Corrado D. MD; et al.
- **Recommendations for interpretation of 12-lead electrocardiogram in the athlete**. ESC REPORT. European Heart Journal 2010. Corrado D. MD; et al.
- **Interpretation of the Electrocardiogram of Young Athletes**. Special Report. Uberoi A. MD; et al. Circulation 2011
- **Electrocardiographic interpretation in athletes: the 'Seattle Criteria'. Br J Sports Med 2013.** Drezner J A; et al. Refinement of the European Society of Cardiology (ESC) criteria
- **Improving the interpretation of the athlete's electrocardiogram.** EDITORIAL. Corrado D. el al. European Heart Journal 2013

European Society of Cardiology (ESC) classification of ECG abnormalities in athletes



Recommendations for interpretation of 12-lead electrocardiogram in the athlete

Group 1: common and training-related ECG changes (>80%)

- Sinus bradycardia
- First-degree AV block
- Incomplete RBBB
- Early repolarization
- Isolated QRS voltage criteria for left ventricular hypertrophy

Group 2: uncommon and training-unrelated ECG changes (<5%)

- T-wave inversion
- ST-segment depression
- Pathological Q-waves
- Left atrial enlargement
- Left-axis deviation/left anterior hemiblock
- Right-axis deviation/left posterior hemiblock
- Right ventricular hypertrophy
- Ventricular pre-excitation
- Complete LBBB or RBBB
- Long- or short-QT interval
- Brugada-like early repolarization

Domenico Corrado, et al. Recommendations for interpretation of 12-lead electrocardiogram in the athlete. European Heart Journal (2010) 31, 243–259

The ‘Seattle Criteria’: Electrocardiographic interpretation in athletes (1)

Normal ECG findings in athletes

1. Sinus bradycardia (≥ 30 bpm)
2. Sinus arrhythmia
3. Ectopic atrial rhythm
4. Junctional escape rhythm
5. 1° AV block (PR interval > 200 ms)
6. Mobitz Type I (Wenckebach) 2° AV block
7. Incomplete RBBB
8. Isolated QRS voltage criteria for LVH
   - Except: QRS voltage criteria for LVH occurring with any non-voltage criteria for LVH such as left atrial enlargement, left axis deviation, ST segment depression, T-wave inversion or pathological Q waves
9. Early repolarisation (ST elevation, J-point elevation, J-waves or terminal QRS slurring)
10. Convex (‘domed’) ST segment elevation combined with T-wave inversion in leads V1–V4 in black/African athletes

Abnormal ECG findings in athletes (1)

T-wave inversion >1 mm in depth in two or more leads V2–V6, II and aVF, or I and aVL (excludes III, aVR and V1)

ST segment depression ≥0.5 mm in depth in two or more leads

Pathologic Q waves >3 mm in depth or >40 ms in duration in two or more leads (except for III and aVR)

Complete left bundle branch block QRS ≥120 ms, predominantly negative QRS complex in lead V1 (QS or rS), and upright monophasic R wave in leads I and V6

Intraventricular conduction delay. Any QRS duration ≥140 ms

Left axis deviation −30° to −90°

Left atrial enlargement Prolonged P wave duration of >120 ms in leads I or II with negative portion of the P wave ≥1 mm in ventricular hypedepth and ≥40 ms in duration in lead V1

Right hipertrophy pattern

R−V1+S−V5>10.5 mm AND right axis deviation >120°

Ventricular pre-excitation PR interval <120 ms with a delta wave (slurred upstroke in the QRS complex) and wide QRS (>120 ms)

Long QT interval*

QTc≥470 ms (male)
QTc≥480 ms (female)
QTc≥500 ms (marked QT prolongation)

(1) And the Right blundle branch block QRS >120ms and <139 ms?

Brugada-like ECG pattern High take-off and descending ST segment elevation followed by a negative T wave in ≥2 leads in V1–V3

Profound sinus bradycardia <30 BPM or sinus pauses ≥ 3 s

Atrial tachyarrhythmias Supraventricular tachycardia, atrial-fibrillation, atrial-flutter

Premature ventricular contractions ≥2 PVCs per 10 s tracing

Ventricular arrhythmias Couplets, triplets and non-sustained ventricular tachycardia

Drezner JA, Ackerman MJ, Anderson J, et al. Br J Sports Med 2013;47:122–124.

(1) In Seattle Criteria normal o abnormal findings in athletes

- **The author have omitted mention of Complete Right bundle branch block QRS ≥120 ms and < 140 ms.**

I send to author a letter about this point about the implication of this and respond by mail

"Dear Dr. Ibarrola,

Thank you for the note. I appreciate your comments regarding RBBB.

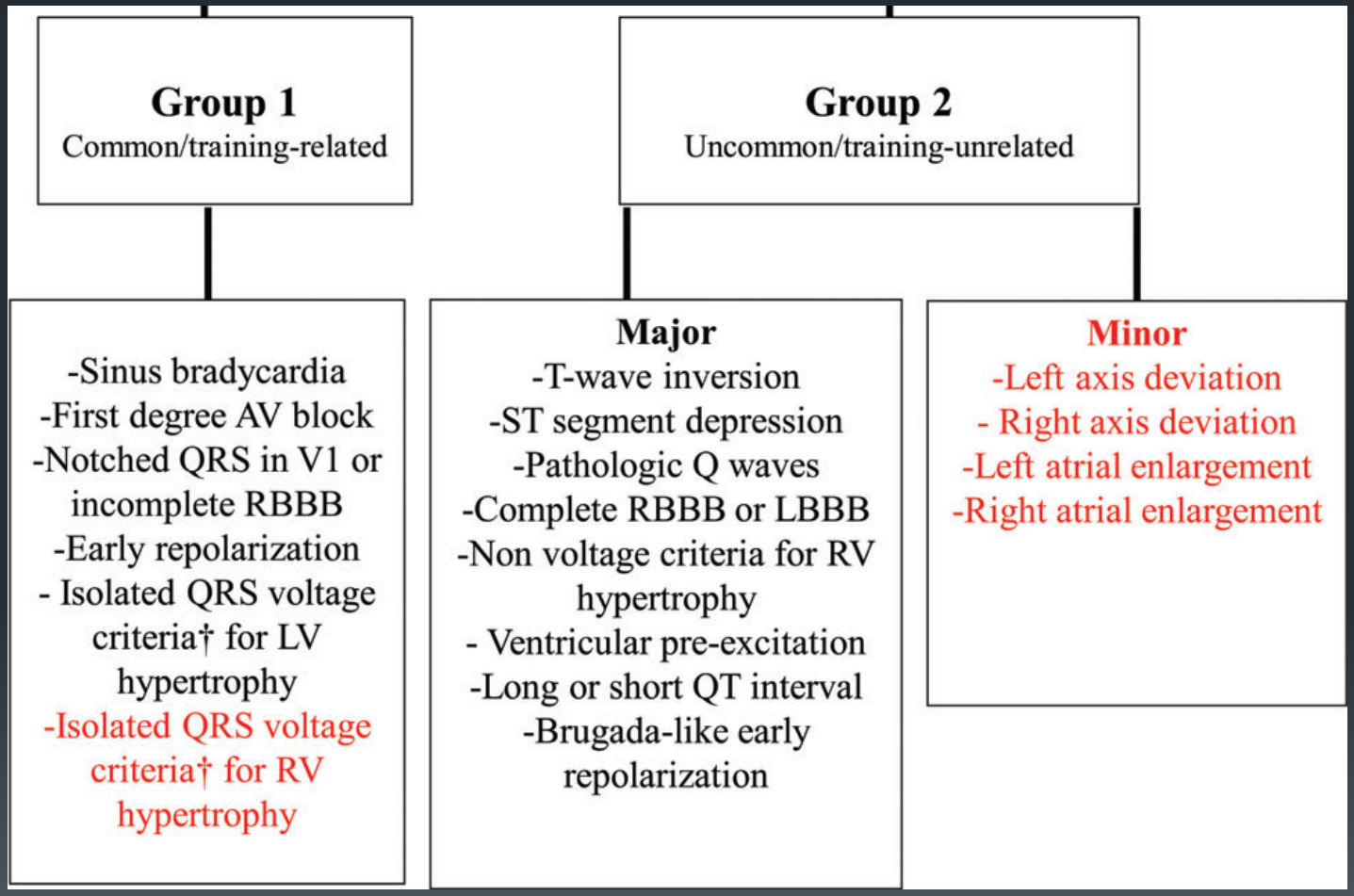
I think the pre-test probability that complete RBBB represents disease in most asymptomatic athlete populations is very low. Thus, in most settings I don't think RBBB has a high positive predictive value and will not be a good distinguisher of disease.

You bring up an important point that was not addressed in the Seattle summit papers -- that RBBB in countries with a high prevalence of Chagas disease should be considered abnormal. This will be considered in any future revisions to the criteria."

Response by Jonathan Drezner, MD

This omitting affected papers compared to ESC recommendation compared with the Seattle Criteria. The complete RBBB have present in 1% of athletes (Pelliccia et al. EHJ 2007) but is normal o abnormal findings in athletes? In countries with Chagas disease, if reasonable? Affected this the support of better false positive in comparative paper's?

Interpretation of the athlete's electrocardiogram



Domenico Corrado et al. Improving the interpretation of the athlete's Electrocardiogram. European Heart Journal (2013) 34, 3606–3609

Electrocardiographic Findings in athletes normal variants

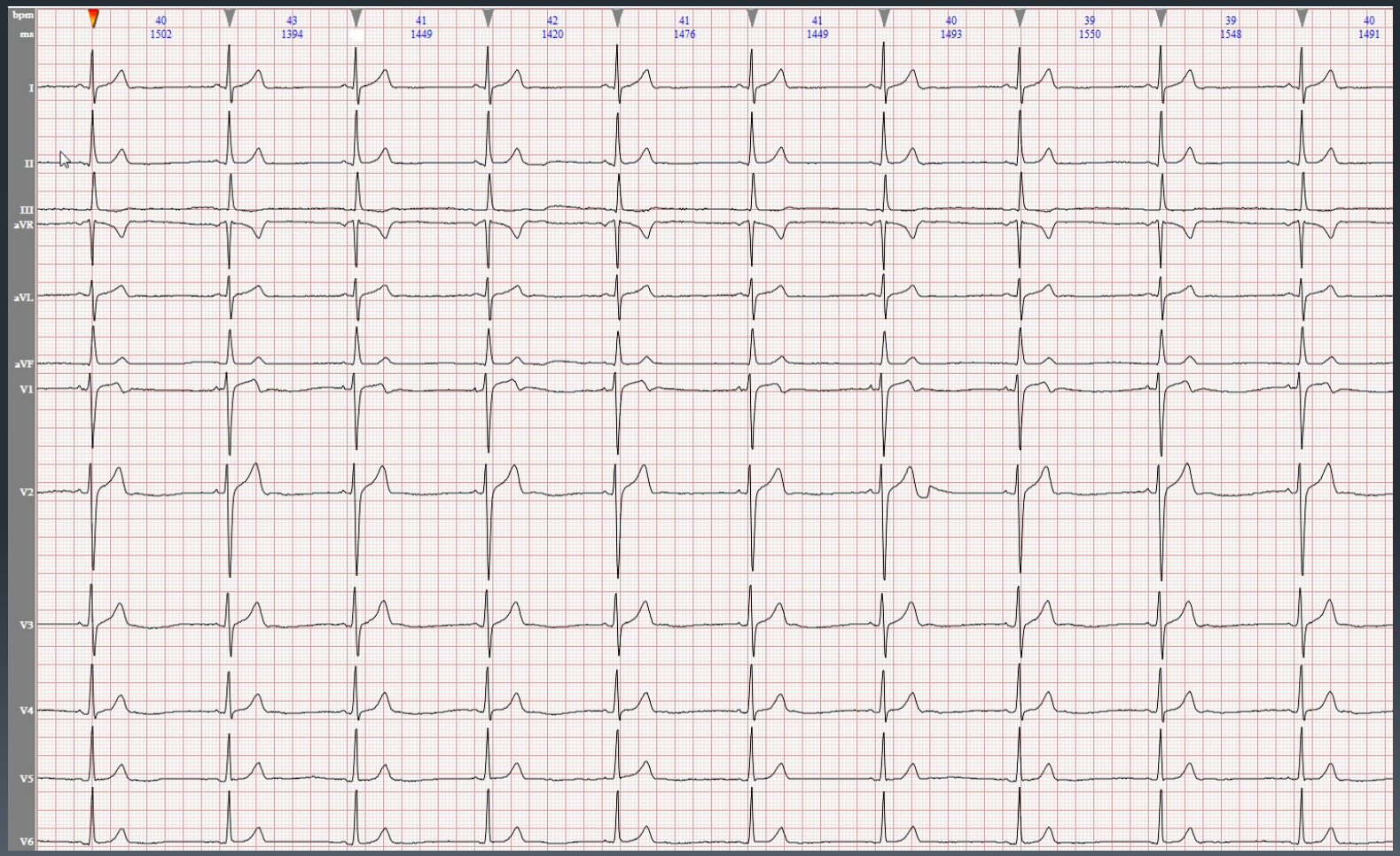
GROUP 1

Athletes normal variants

Increased vagal tone

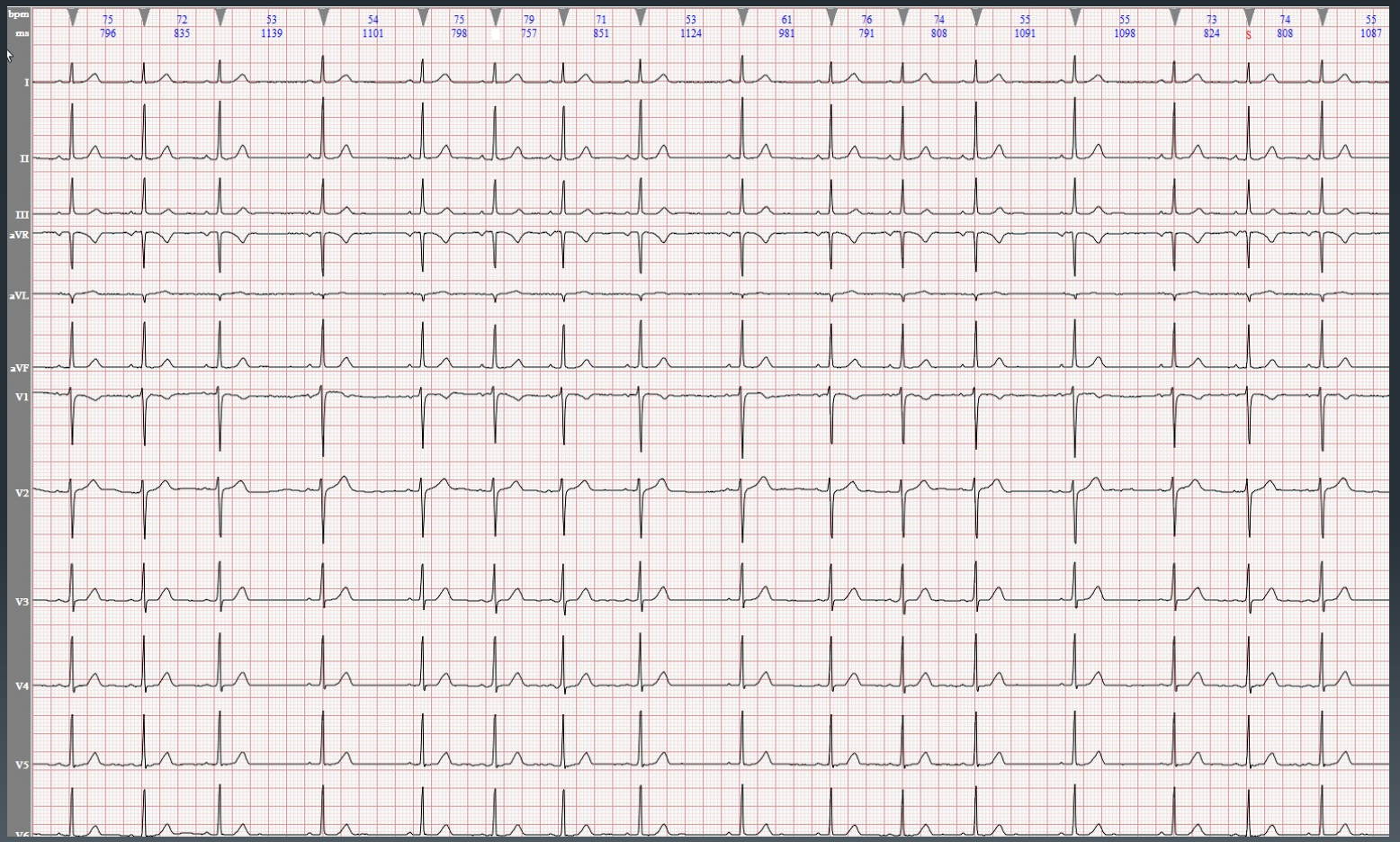
Changes of increased cavity dimensions and wall thickness

Sinus bradycardia (≥ 30 bpm). P wave must have a normal axis in the frontal plane (0–90°s)



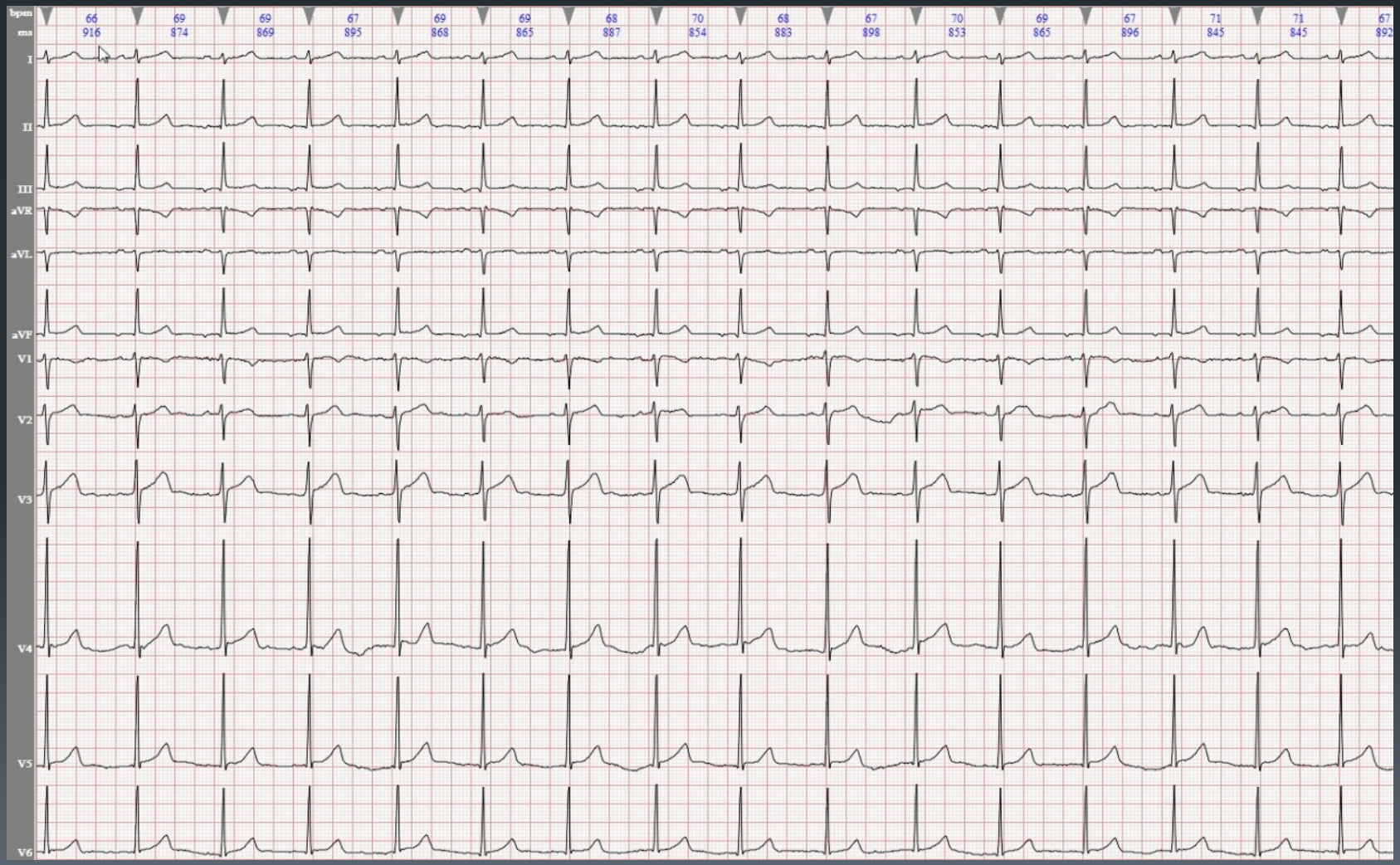
Male 27 years old. Rugby player. Sinus bradycardia 41 bpm

Sinus arrhythmia

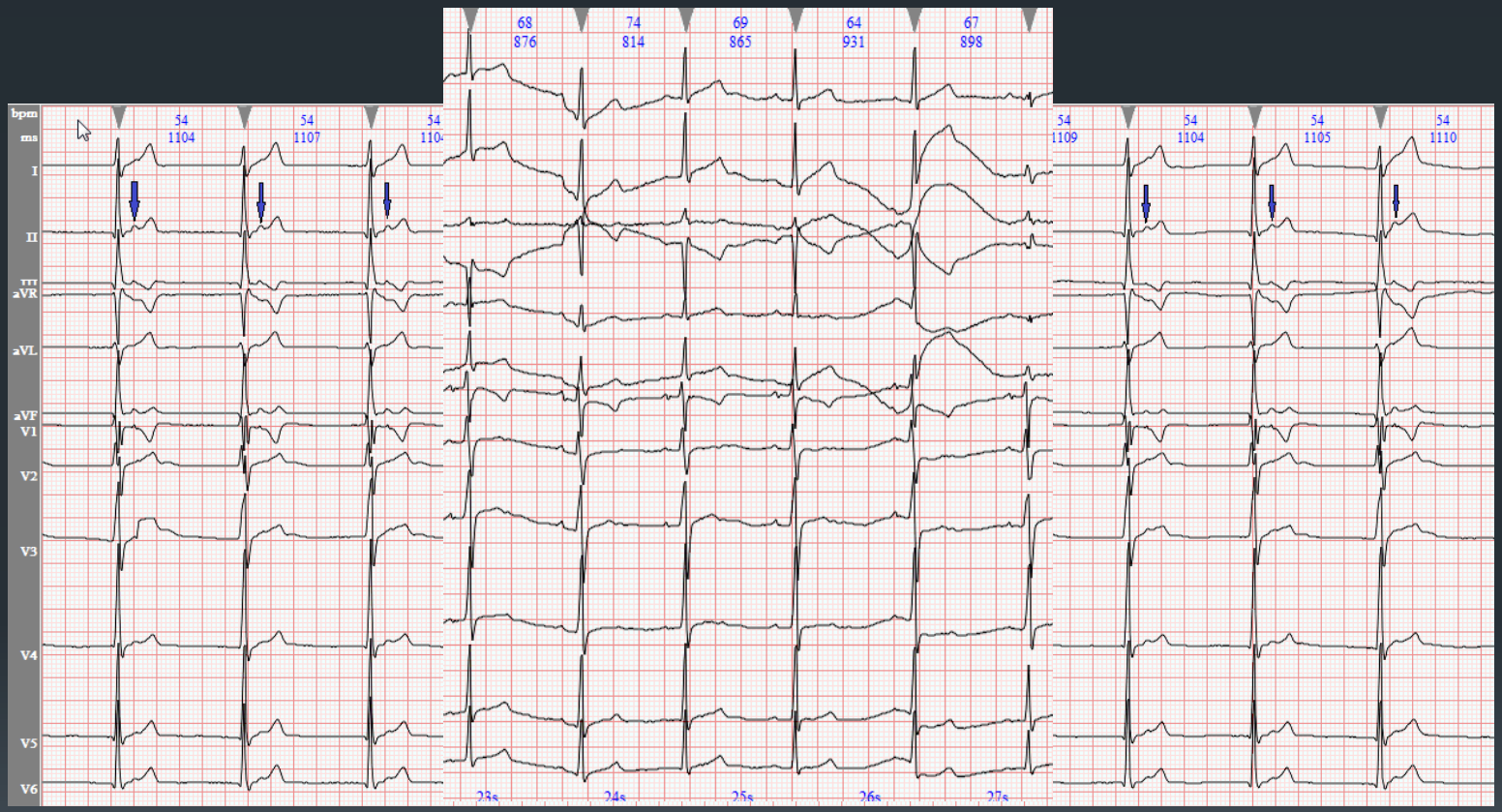


Female 14 years old. Voley. 64 BPM. Sinus arrythmia

Ectopic atrial rhythm: P waves are present but are a different morphology compared to the sinus P wave, negative in the inferior leads (II, III and aVF)

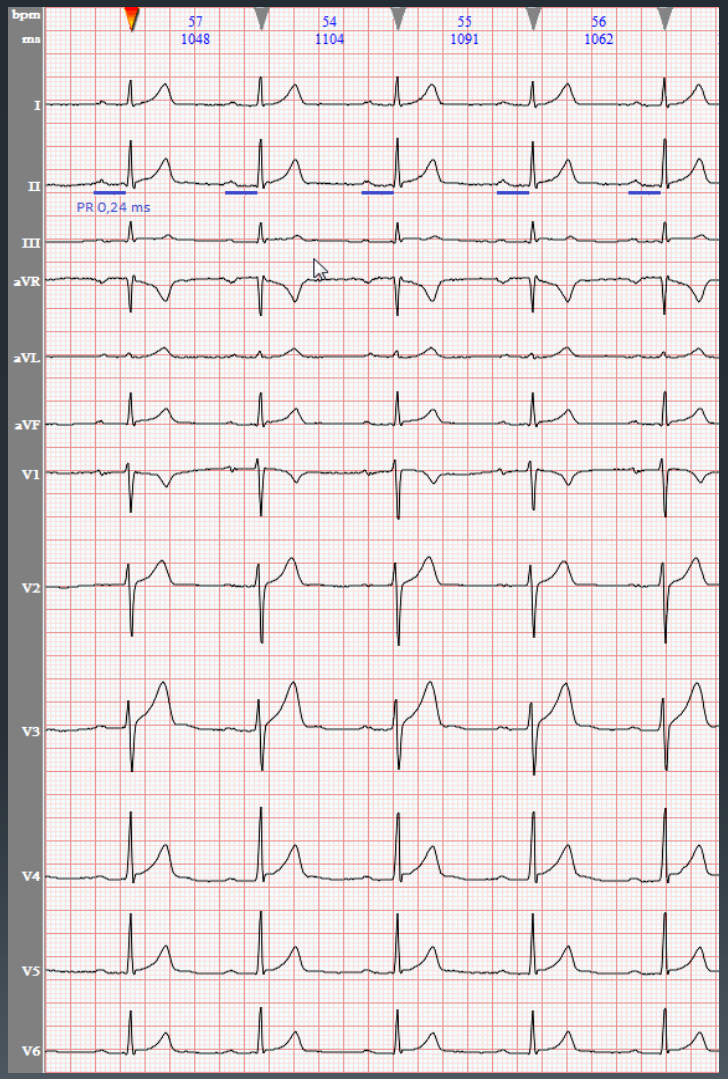


Junctional escape rhythm or nodal rhythm



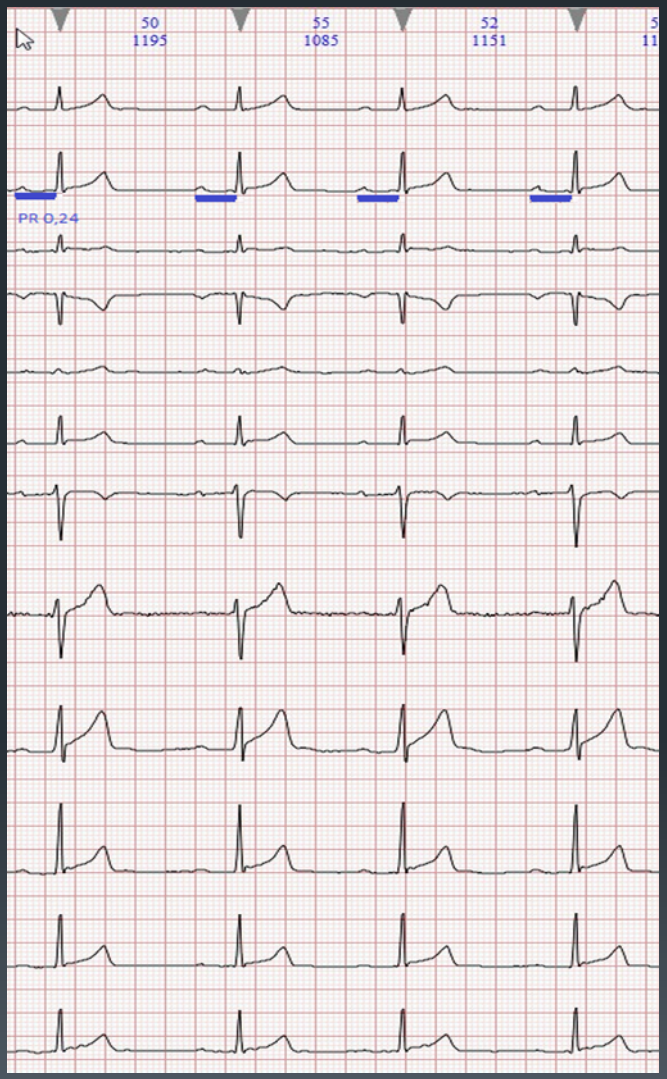
Male 15 years old. Rugby player. Asyntomatic. Nodal rhytmin

First-degree AV block: PR interval is prolonged (>200 ms)



23 years old

2011

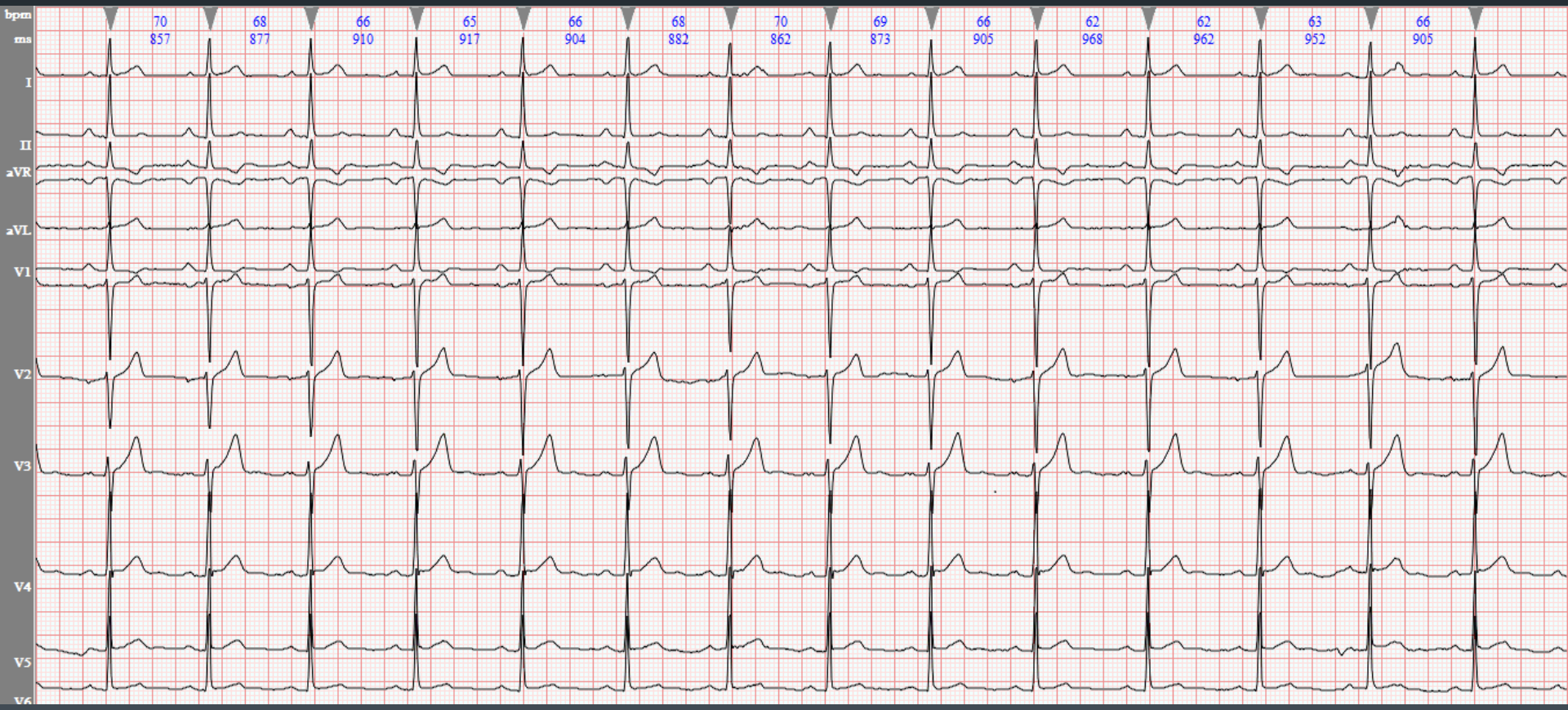


27 years old

2015

Male, Rugby player, asymtomatic with BAV 1er grade 0,24 ms

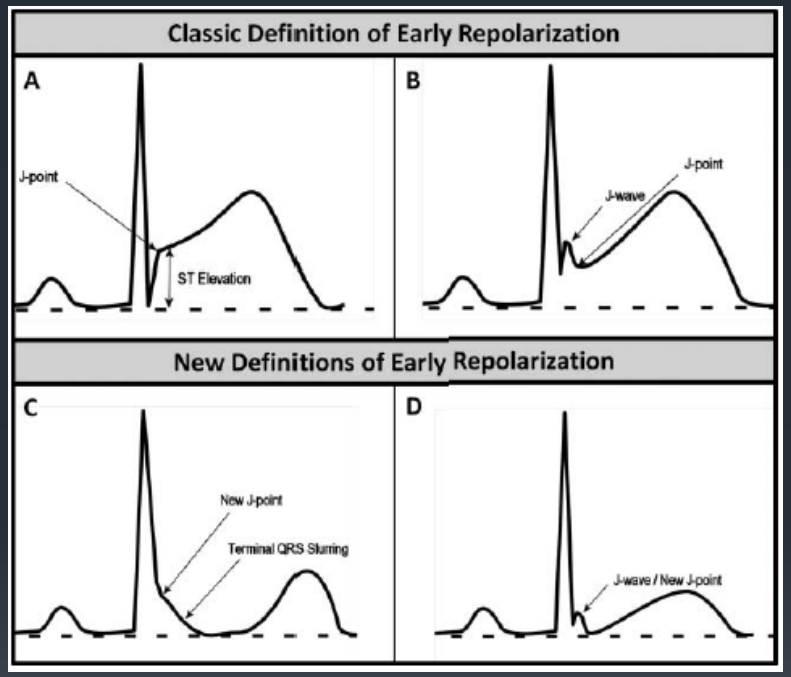
Second-degree AV block: Mobitz type I (Wenckebach)

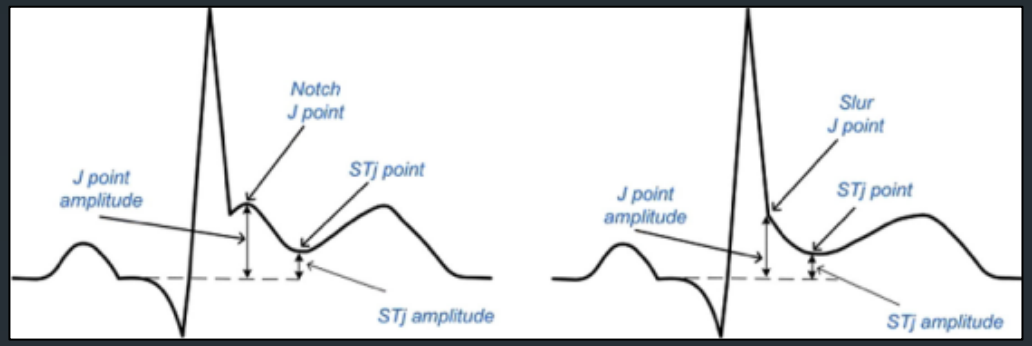


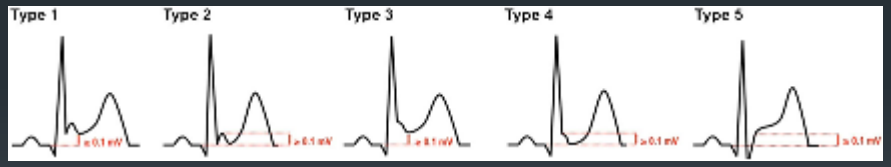
Male 32 years old. Asymtomatic. Intensive Spining.

Early repolarization: concave ST segment elevation in the precordial leads.

New definitions of Early Repolarization



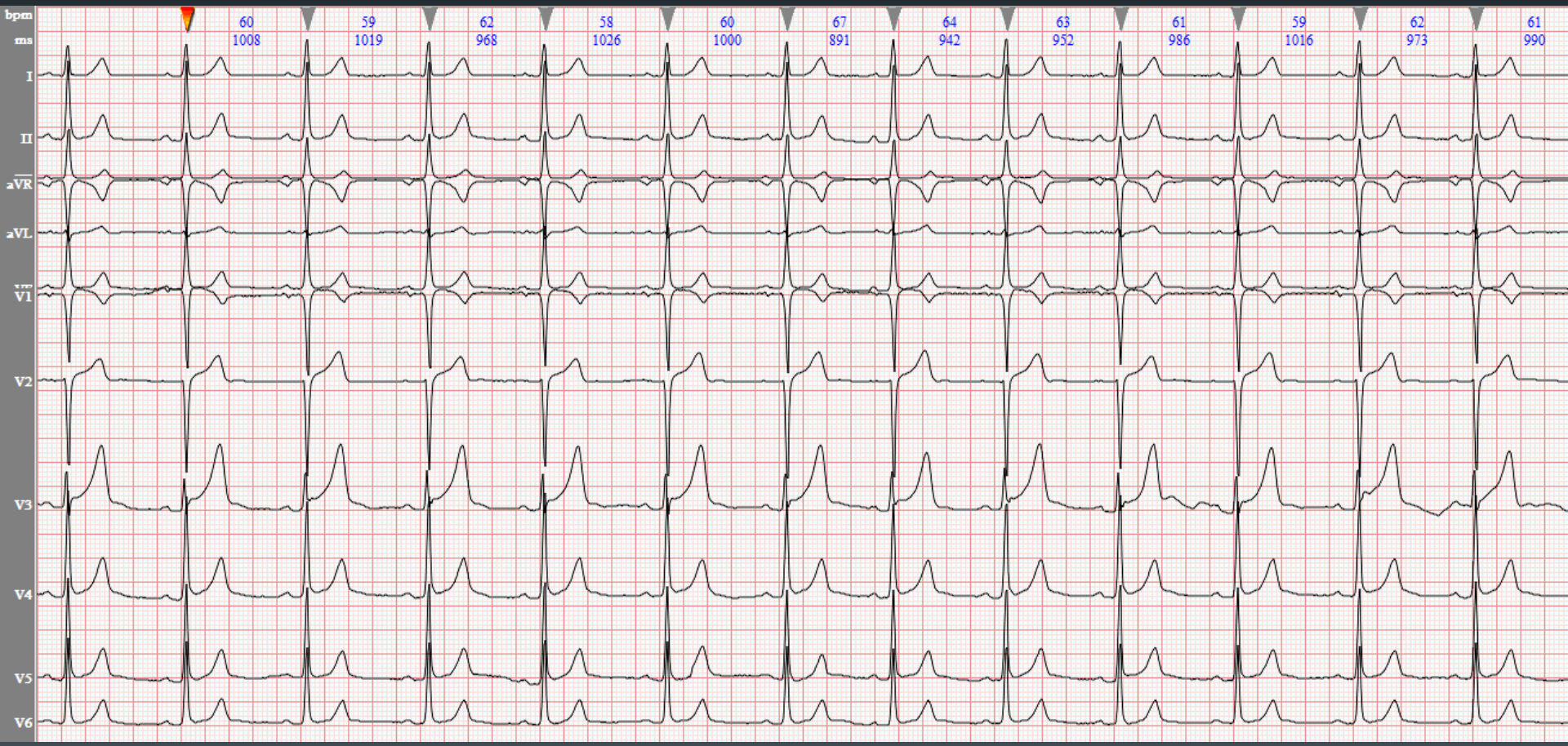


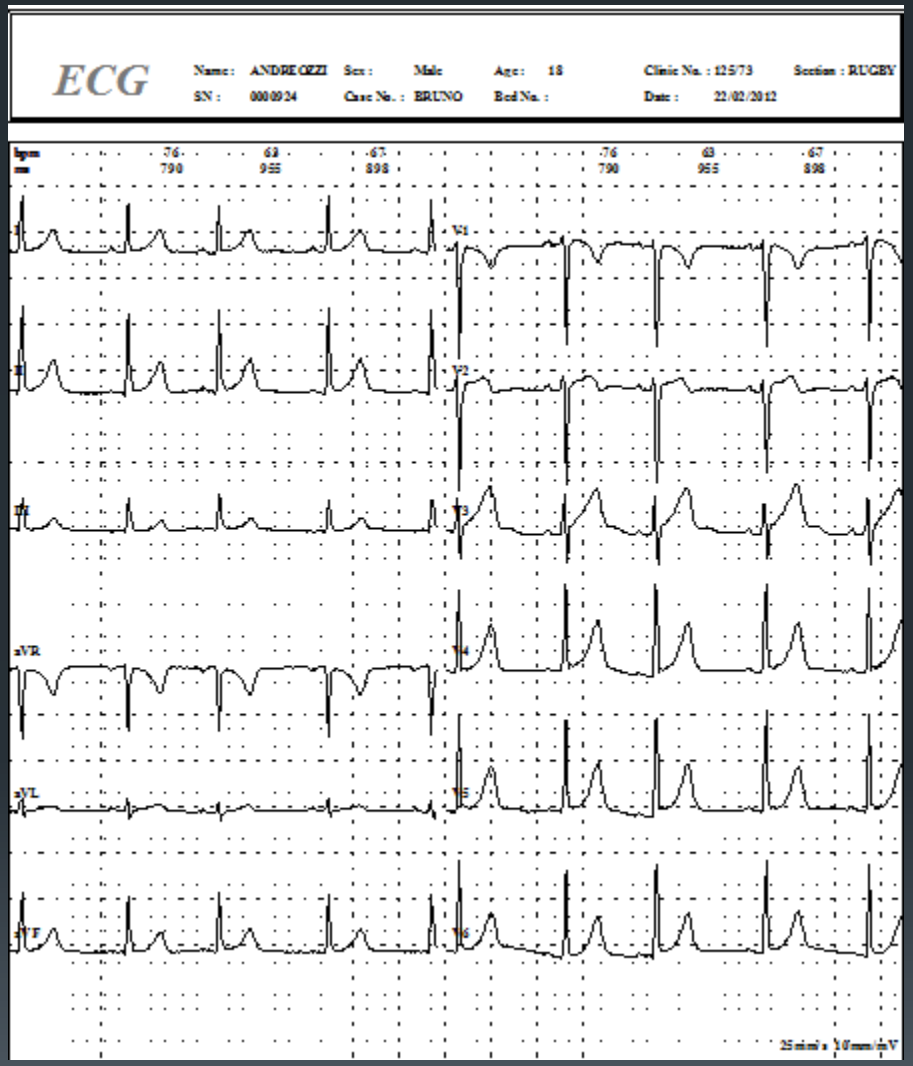


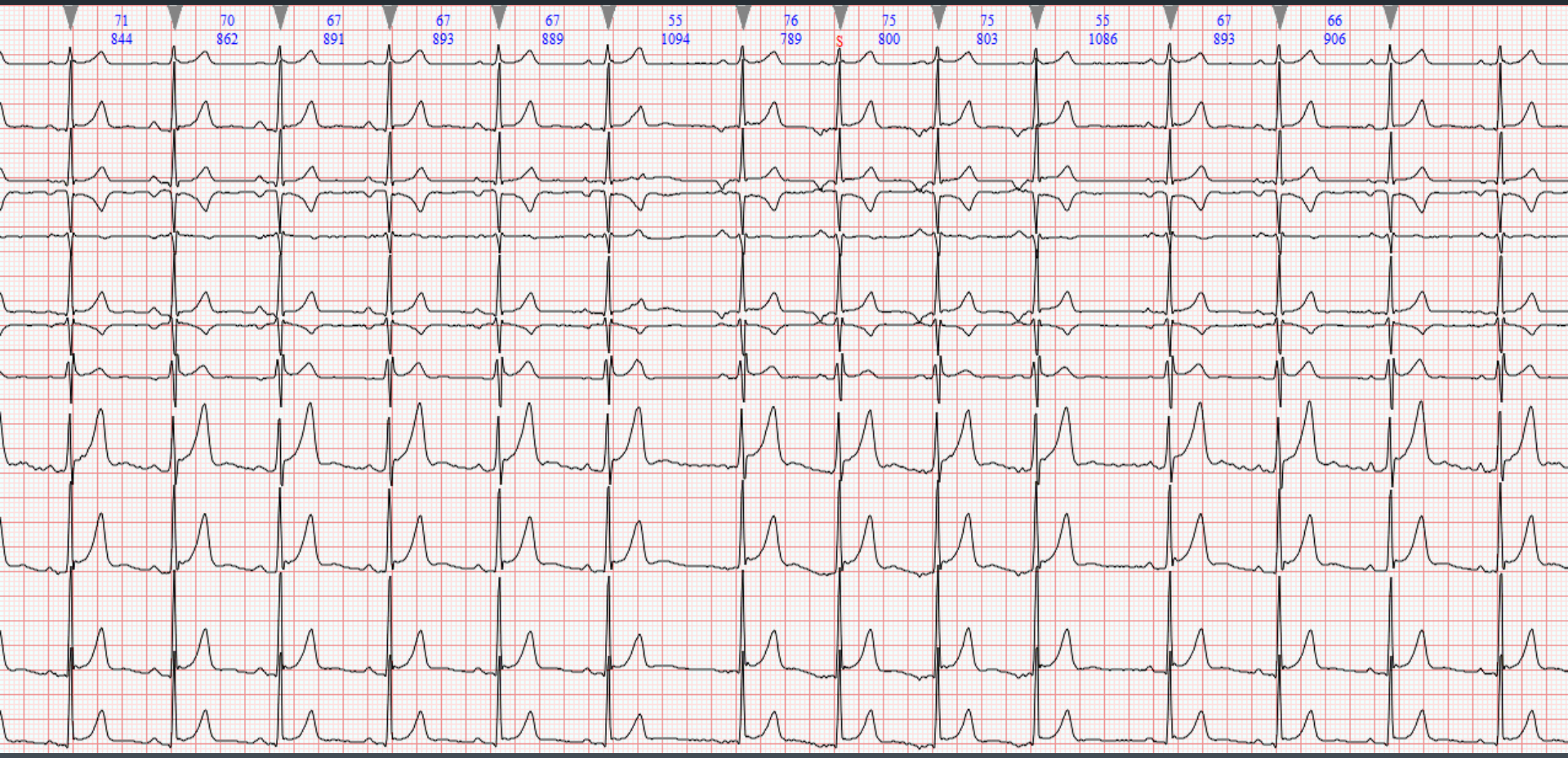
Types 1, 3 and 5 all have an elevated ST amplitude ≥0.1 mV with or without a notch or slur while Types 2 and 4 have the peak of a notch or onset of a slur ≥0.1 mV but without ST elevation.

Peter W. Macfarlane. J wave patterns — morphology, prevalence and nomenclature. J Electrocardiol. 2013 Nov-Dec;46(6):505-9

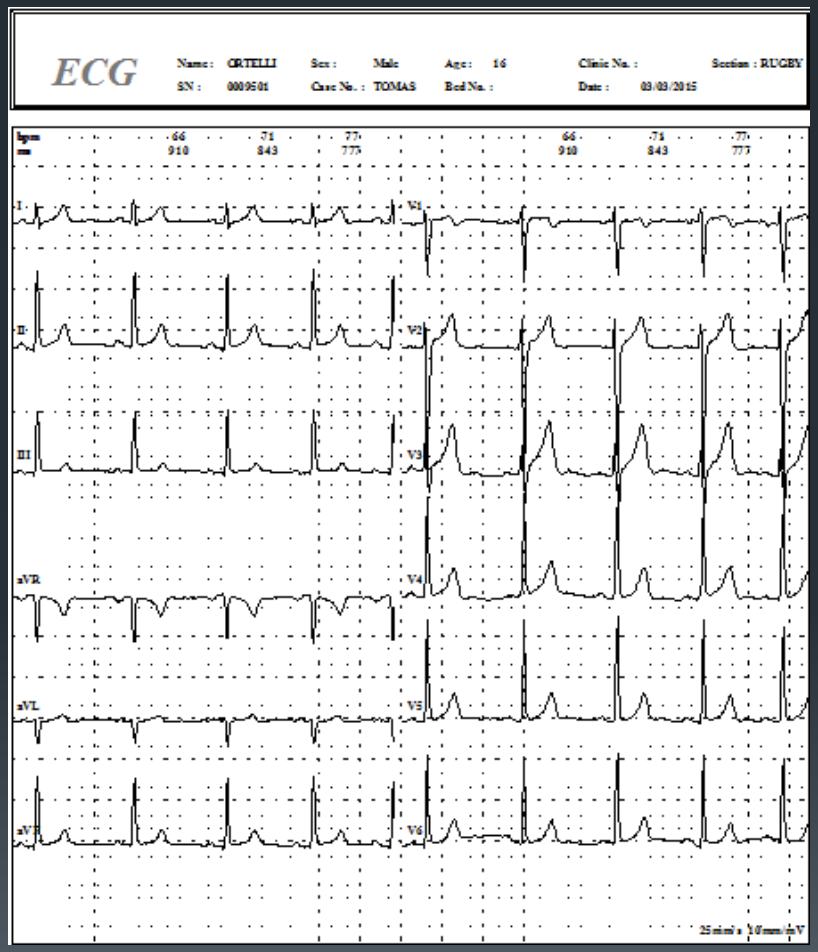
Early repolarization

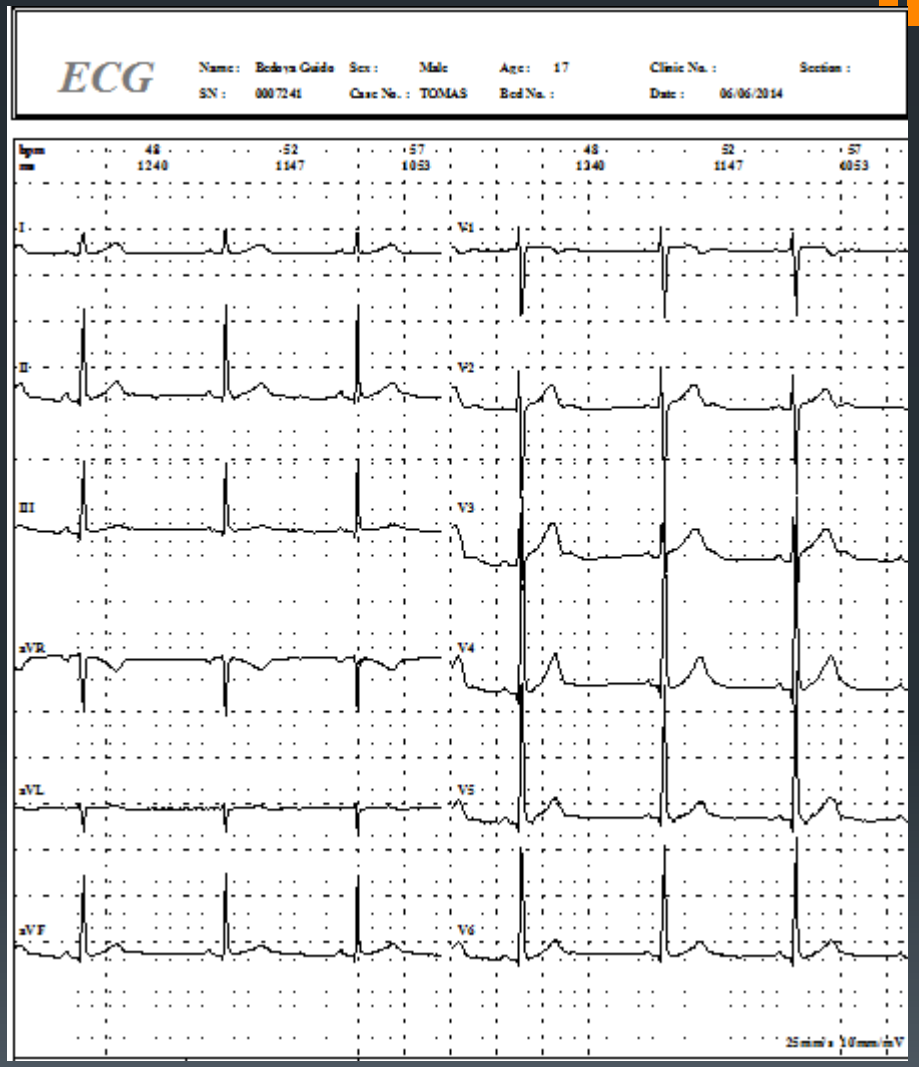


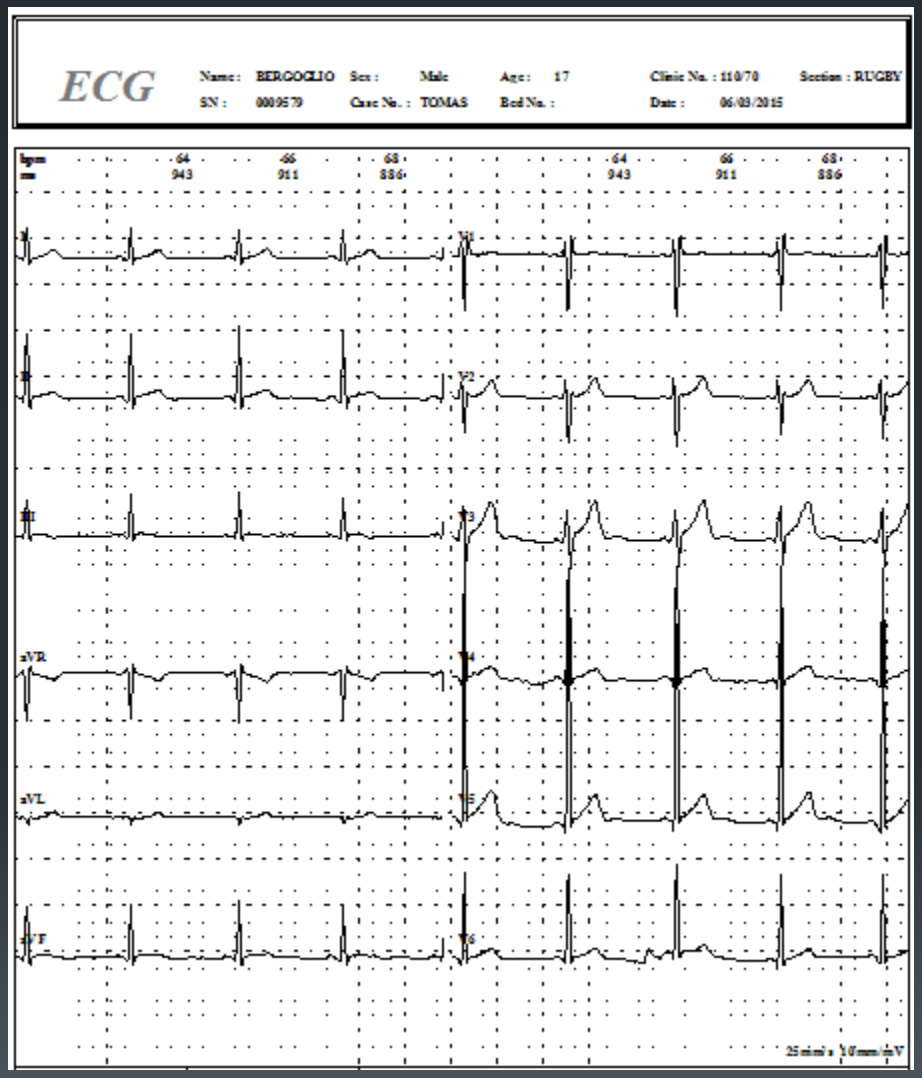

ECG
Name : ANDREOZZI
Sex : Male
Age : 18
Clinic No. : 125/73
Section : RUGBY
SN : 000024
Case No. : BRUNO
Bed No. :
Date : 22/02/2012
bpm 76 63 67 76 63 67
ms 790 955 898 790 955 898
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
25 mm/s 10 mm/mV


71
844
70
862
67
891
67
893
67
889
55
1094
76
789
S
75
800
75
803
55
1086
67
893
66
906

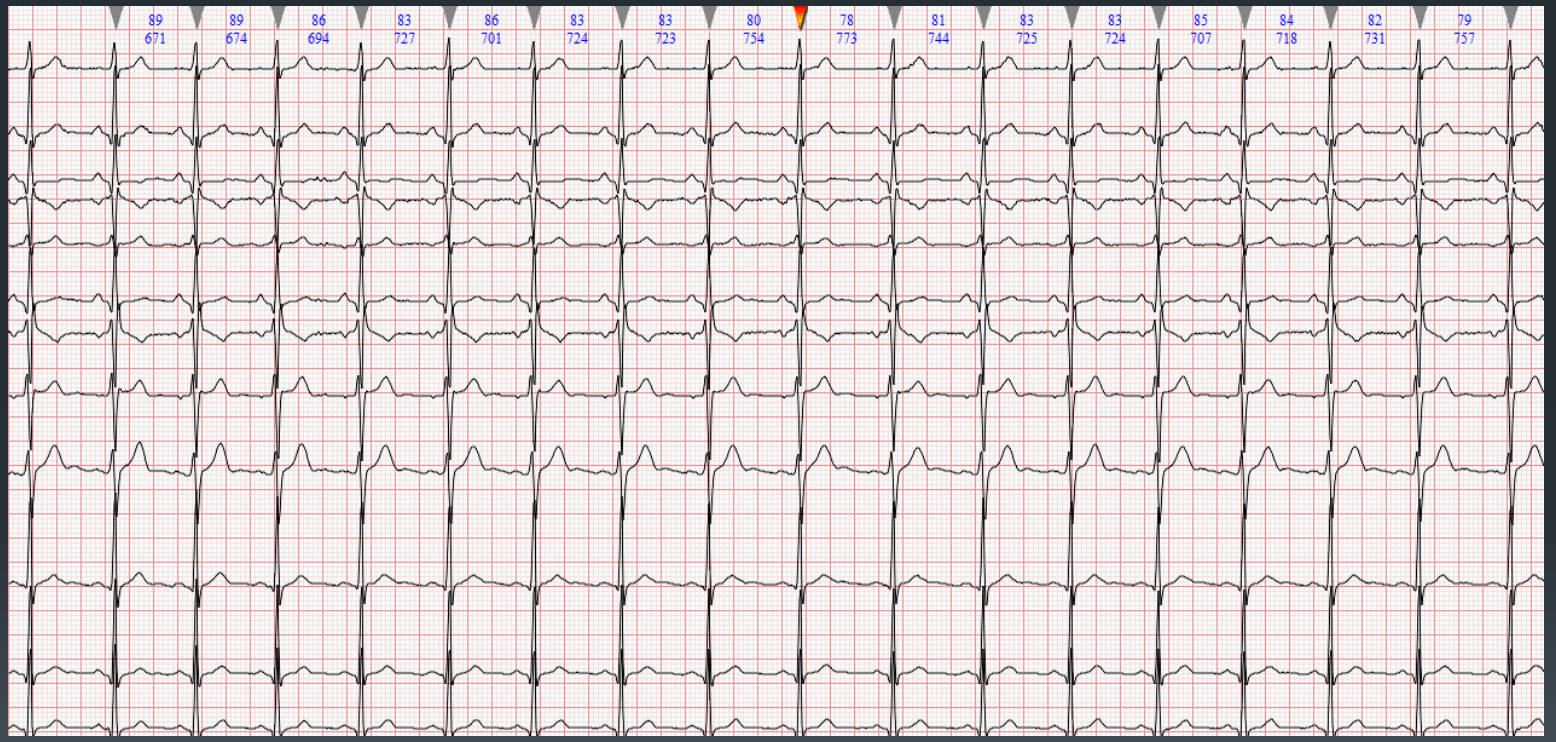
Isolated QRS voltage criteria for LVH for Sokolow-Lyon criterion






ECG
Name : BERGOGLIO Sex : Male Age : 17 Clinic No. : 110/70 Section : RUGBY
SN : 0009579 Case No. : TOMAS Bed No. : Date : 06/03/2015
bpm 64 66 68 64 66 68
ms 943 911 886 943 911 886
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
25 mm/s 10 mm/mV

Incomplete right bundle branch block



Male 17 years. IRBBB

Abnormal electrocardiographic findings in athletes

GROUP 2

Mimics incomplete Right bundle branch block

- Abnormal IRBBB pattern associated with other ECG abnormalities, T wave inversion involving the mid-precordial leads to V1–V3, prolonged S wave upstrokein individuals >14 years of age, low limb-lead voltages, prolonged S wave upstroke and/or premature ventricular beats with a left bundle branch block (LBBB) morphology and Epsilon waves in ARRHYTHMOGENIC RIGHT VENTRICULAR CARDIOMYOPATHY

- Brugada-ECG pattern, which is characterized by a high take-off and downsloping ST segment elevation followed by a negative T wave in ≥2 leads in V1–V3. ‘J wave’ reflects early repolarisation with J point elevation and a high take-off with downsloping ST segment followed by a negative T wave

Criteria for diagnosis of ARVC/D

1. Family history

Major

- Familial disease confirmed at necropsy or surgery.

Minor

- Family history of premature sudden death (<35 years of age) due to suspected ARVC/D.
- Family history (clinical diagnosis based on present criteria).

2. ECG depolarization/conduction abnormalities

Major

- Epsilon waves or localized prolongation (>110 ms) of QRS complex in right precordial leads (V1-V3).

Minor

- Late potentials on signal-averaged ECG.

3. ECG repolarization abnormalities

- Minor
- Inverted T waves in right precordial leads (V2 and V3) in people >12 years of age and in absence of right bundle branch block.

4. Arrhythmias

Minor

- Sustained or nonsustained left bundle branch block-type ventricular tachycardia documented on ECG or Holter monitoring or during exercise testing.
- Frequent ventricular extrasystoles (>1000/24 h on Holter monitoring).

5. Global or regional dysfunction and structural alterations*

Major

- Severe dilatation and reduction of RV ejection fraction with no or mild LV involvement.
- Localized RV aneurysms (akinetic or dyskinetic areas with diastolic bulgings). Severe segmental dilatation of RV.

Minor

- Mild global RV dilatation or ejection fraction reduction with normal LV.
- Mild segmental dilatation of RV.
- Regional RV hypokinesia.

6. Tissue characteristics of walls

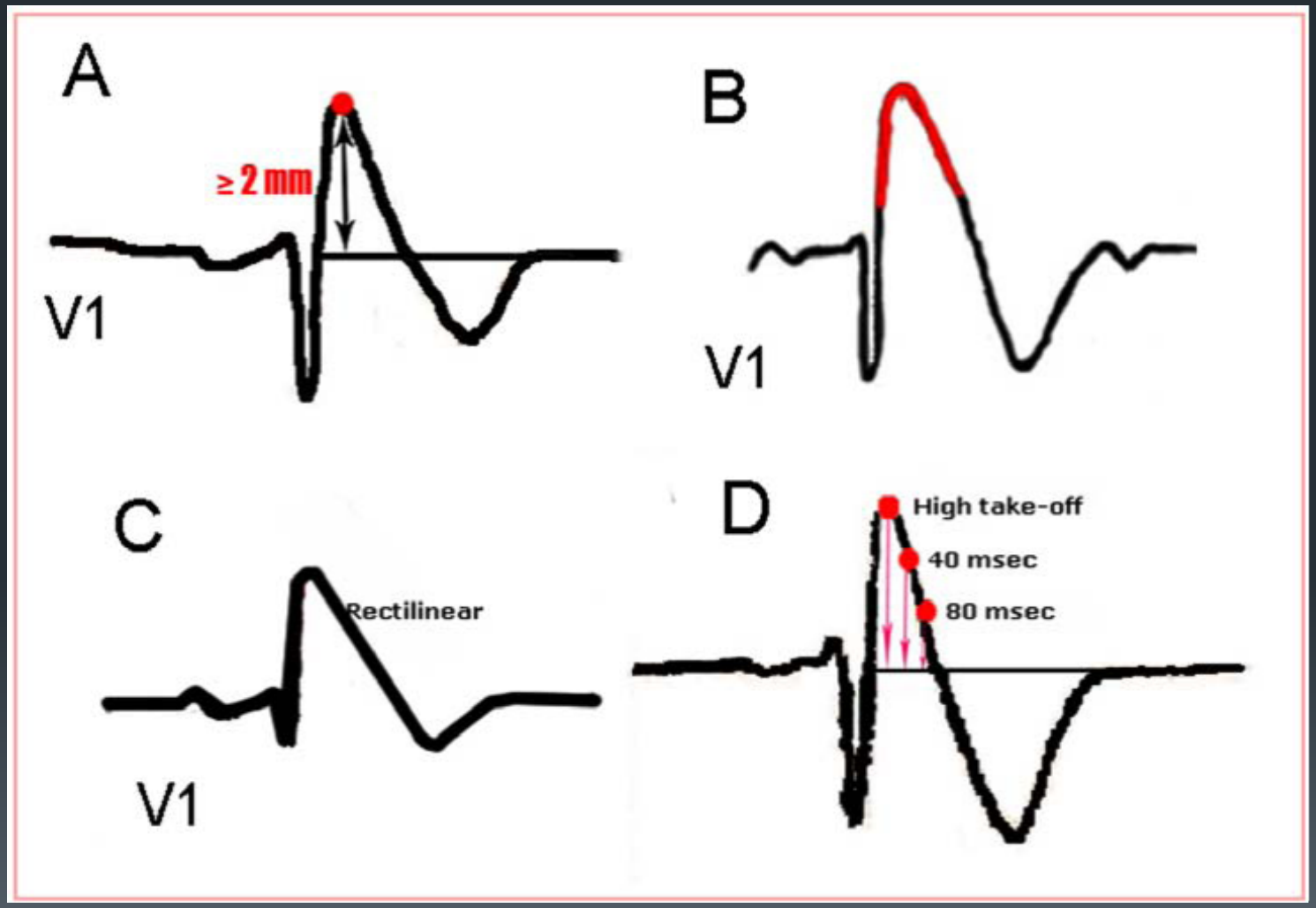
- Major
- Fibro-fatty replacement of myocardium on endomyocardial biopsy.

- * Detected by echocardiography, angiography, magnetic resonance imaging, or radionuclide scintigraphy.

Modified from McKenna et al.

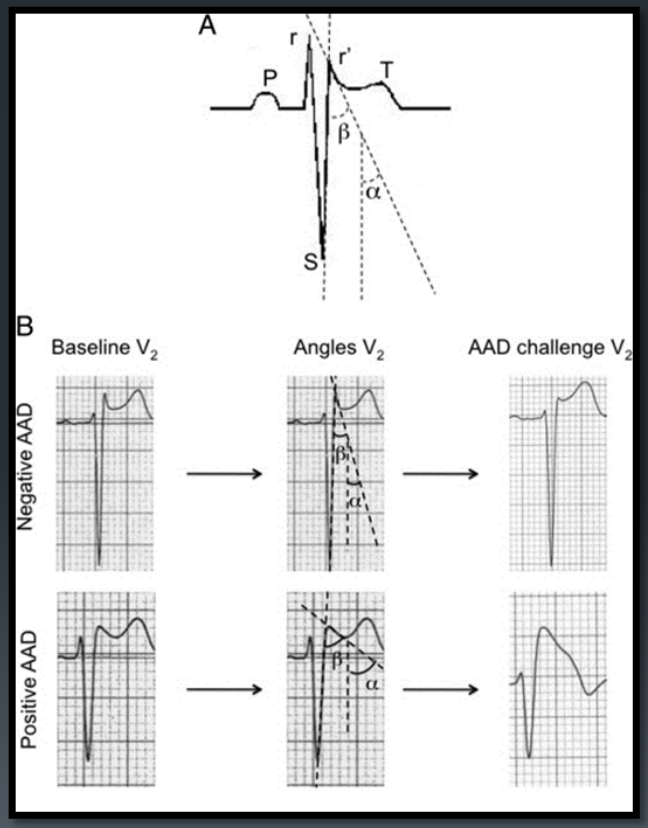
BRUGADA PATTERN

TYPE-1

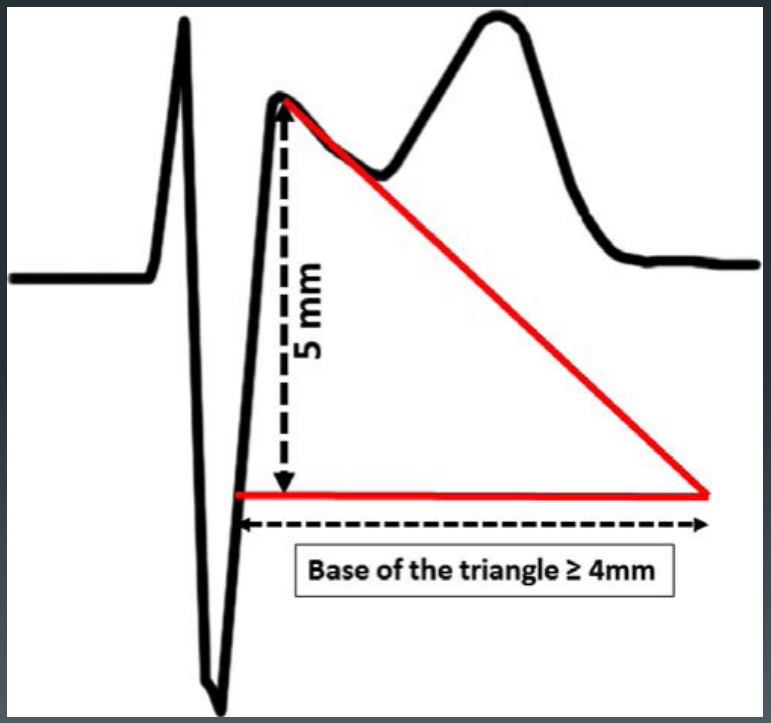


TYPE-2

- The differential diagnosis of Type-2 Brugada pattern and electrocardiogram of athletes



Chevallier S, et al. New electrocardiographic criteria for discriminating between Brugada types 2 and 3 patterns and incomplete right bundle branch block.



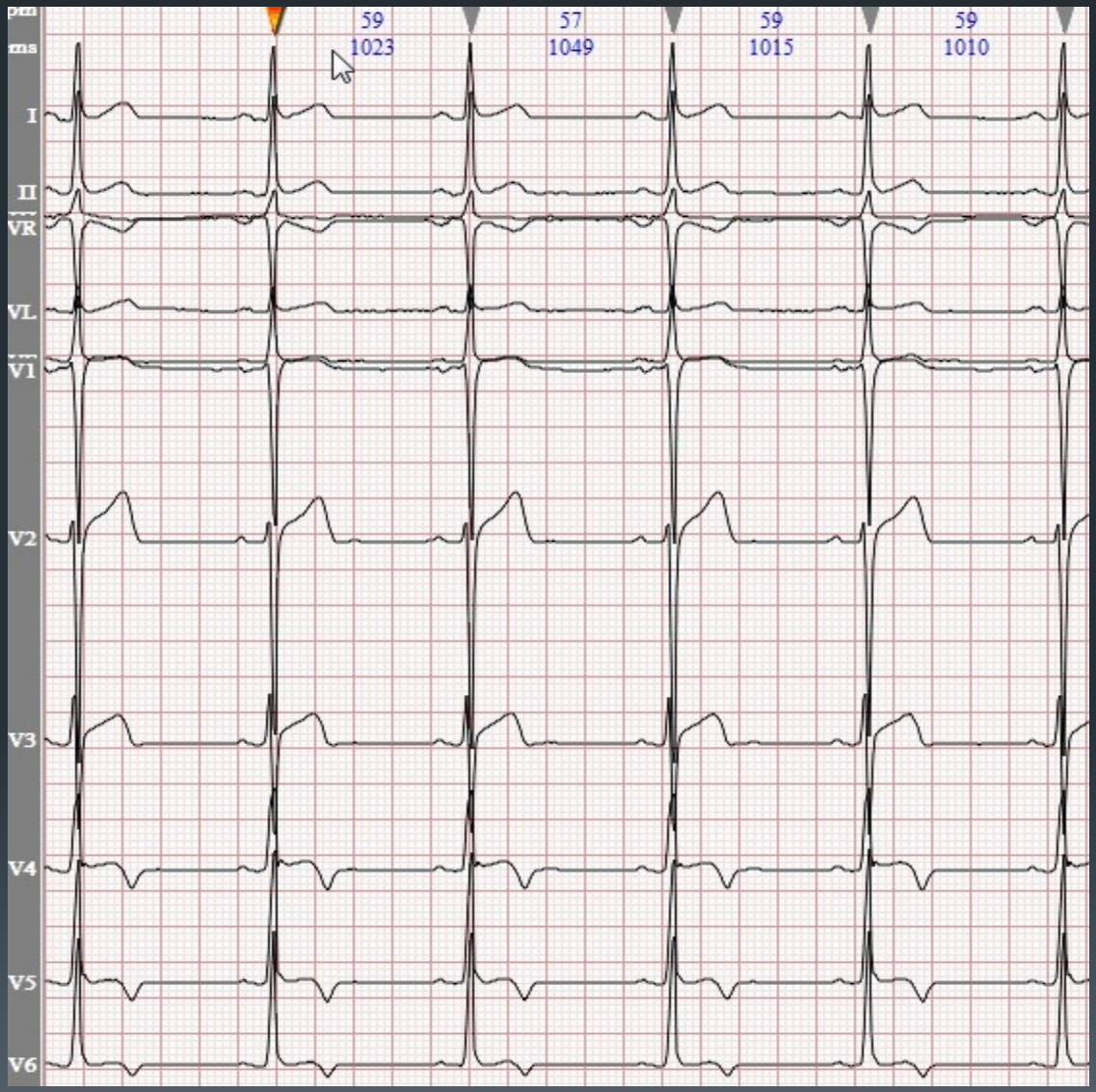
Bayes de Luna A, Garcia-Niebla J, Baranchuk. A. New electrocardiographic features in Brugada syndrome. Curr Cardiol Rev. 2014 Aug;10(3):175-80.

- **T wave inversion.** >1 mm in depth in two or more leads V2–V6, II and aVF or I and aVL (excludes III, aVR and V1)
- **ST segment depression**. ≥0.5 mm in depth in two or more leads
- **Pathological Q waves**. >3 mm in depth or >40 ms in duration in two or more leads (except III and aVR)
- **Complete left bundle branch block**. QRS≥120 ms, predominantly negative QRS complex in lead V1 (QS or rS), and upright monophasic R wave in leads I and V6
- **Intraventricular conduction delay**. Any QRS duration ≥140 ms
- **Left axis deviation**. −30° to −90°
- **Left atrial enlargement**. Prolonged P wave duration of >120 ms in leads I or II with negative portion of the P wave≥1 mm in depth and ≥40 ms in duration in lead V1
- **Right ventricular hypertrophy pattern**. R-V1+S-V5>10.5 mm AND right axis deviation >120°
- **Ventricular pre-excitation**. PR interval <120 ms with a delta wave (slurred upstroke in the QRS complex) and wide QRS (>120 ms)
- **Long QT interval.** QTc≥470 ms (male); QTc≥480 ms (female); QTc≥500 ms (marked QT prolongation)
- **Short QT interval**. QTc≤320 ms
- **Profound sinus bradycardia.** <30 BPM or sinus pauses ≥ 3 s
- **Atrial tachyarrhythmias**. Supraventricular tachycardia, atrial-fibrillation, atrial-flutter
- **Premature ventricular contractions**. ≥2 PVCs per 10 s tracing. LBBB morphology and an inferior axis (positive in the inferior leads) originate in right ventricular outflow tract. LBBB morphology and superior axis (negative in the inferior leads) originate in the right ventricular free wall or apex and are more suggestive of ARVC
- **Ventricular arrhythmias**. Couplets, triplets and non-sustained ventricular tachycardia

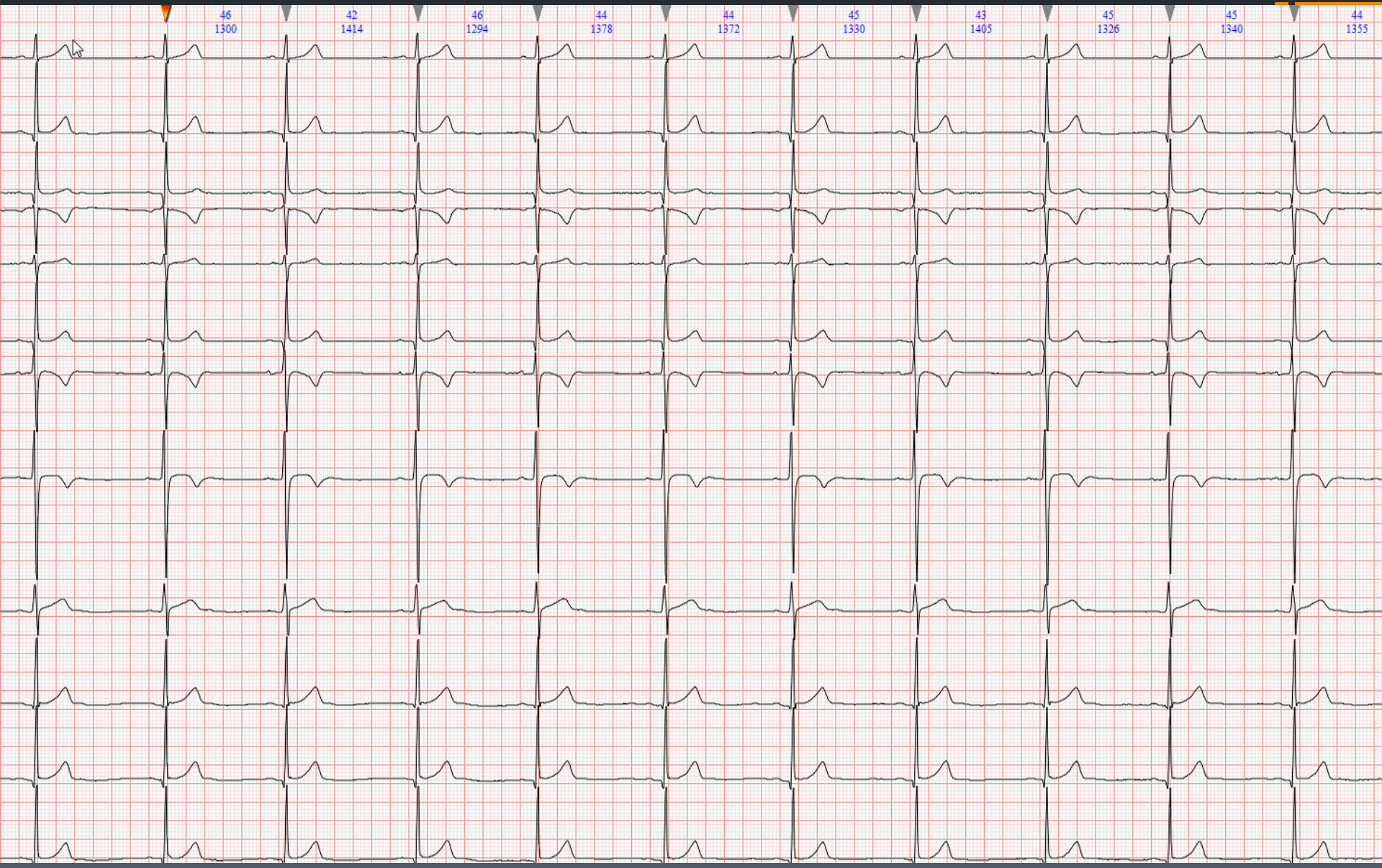
Cadiomyopathyes

- HYPERTROPHIC CARDIOMYOPATHY. 12-lead ECG pattern is abnormal in 75% to 95% of HCM patients
- DILATED CARDIOMYOPATHY. individuals with asymptomatic LV dysfunction, 90% have abnormal ECG findings. 1) LVH in the anterior precordial leads; (2) low limb lead voltage and (3) poor precordial R wave progression
- LV NON-COMPACTION. ECG abnormalities in isolated LVNC are common but nonspecific. most common abnormalities in this series included repolarisation changes (72%), QT prolongation (52%), ST segment depression (51%), TWI (41%), LVH voltage criteria (38%), IVCD (31%) including LBBB (19%) and RBBB (3%), and LAE (26%)
- OTHER ECG FINDINGS POSSIBLY SUGGESTIVE OF A CARDIOMYOPATHY, nonspecific IVCD with QRS duration <140 ms, and isolated (one per tracing) ectopic/premature ventricular contractions (PVCs) have been associated with an underlying cardiomyopathy in non-athletic populations. asymptomatic athletes with an isolated complete (≥120 ms-139 ms) or incomplete (100–119 ms) RBBB, no further diagnostic evaluation is require

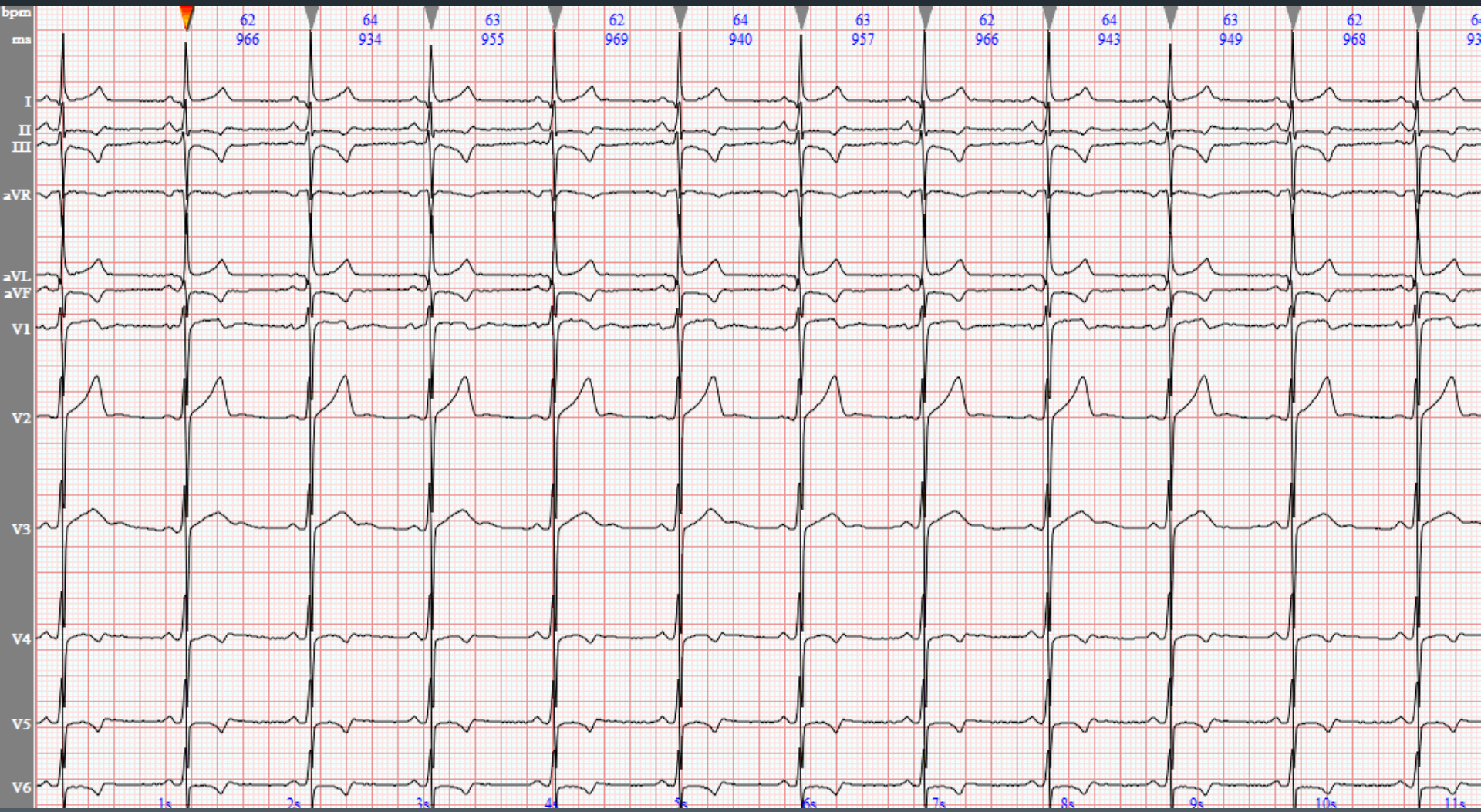
T wave inversion. >1 mm in depth in two or more leads V2–V6, II and aVF or I and aVL



Male 14 years old. Rugby. Asymtomatic.

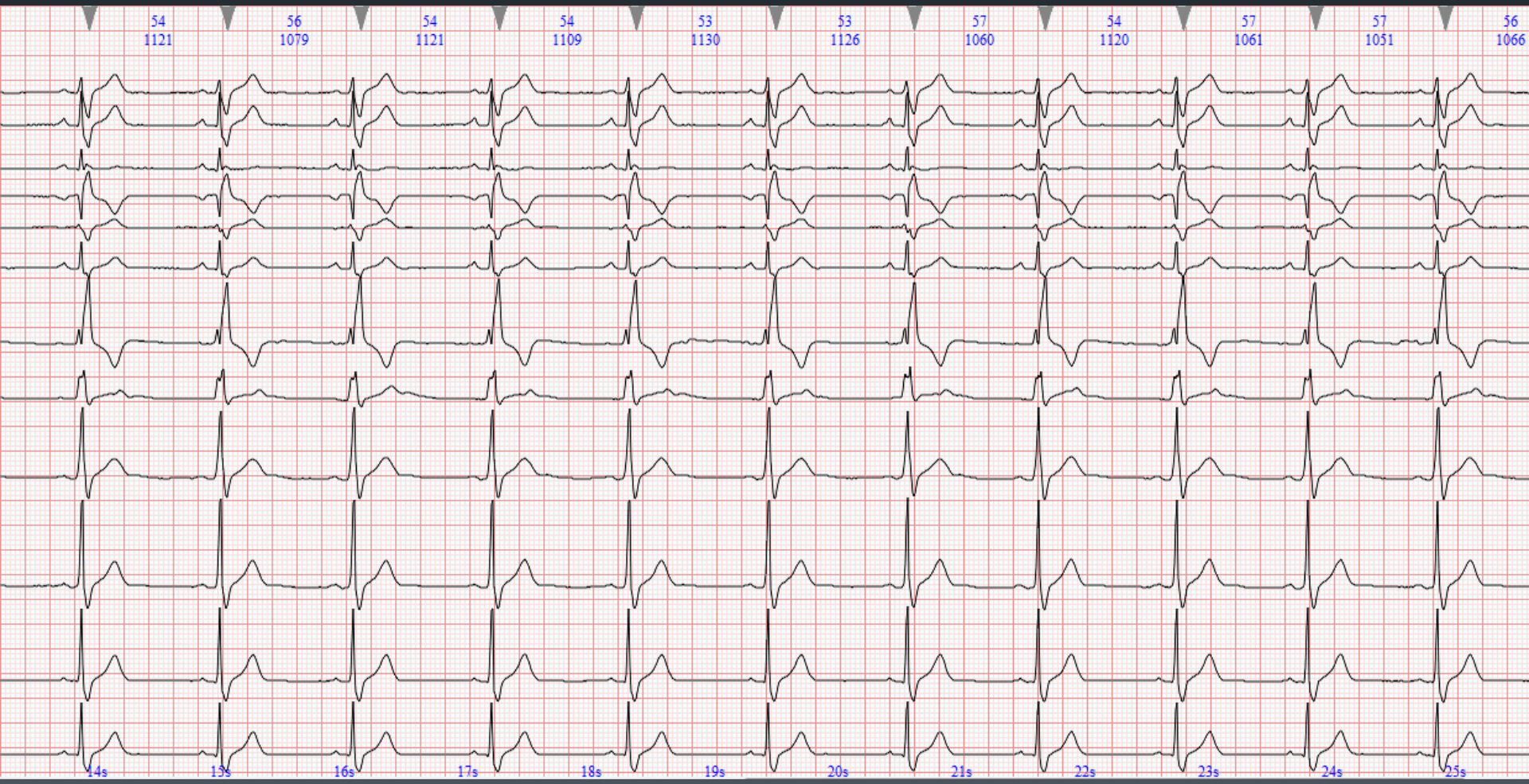


Male 16 yeras. Rugby.



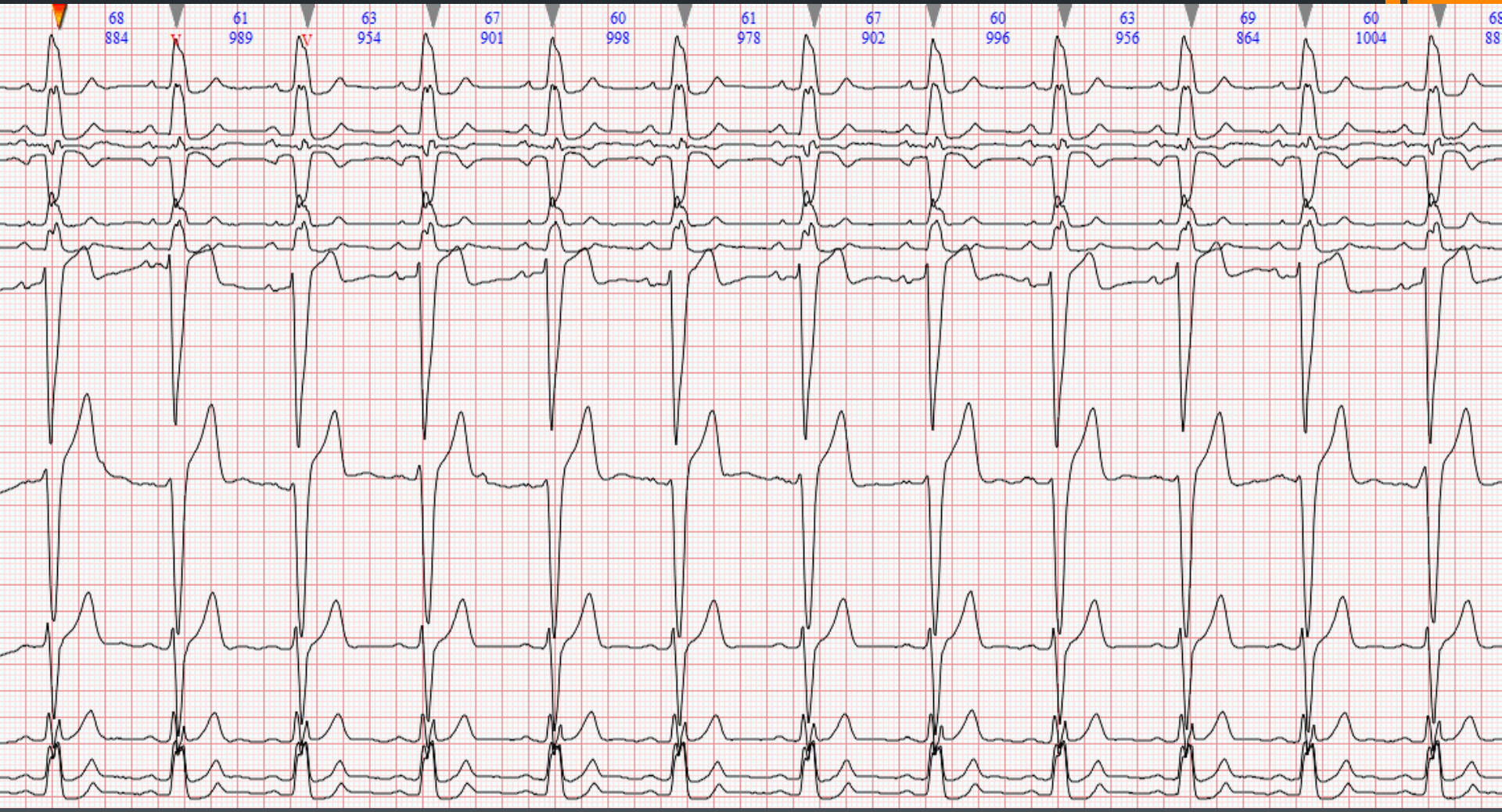
Male 22 years. Rugby. Asymtomatic.

Complete Right bundle branch block. QRS≥120 ms



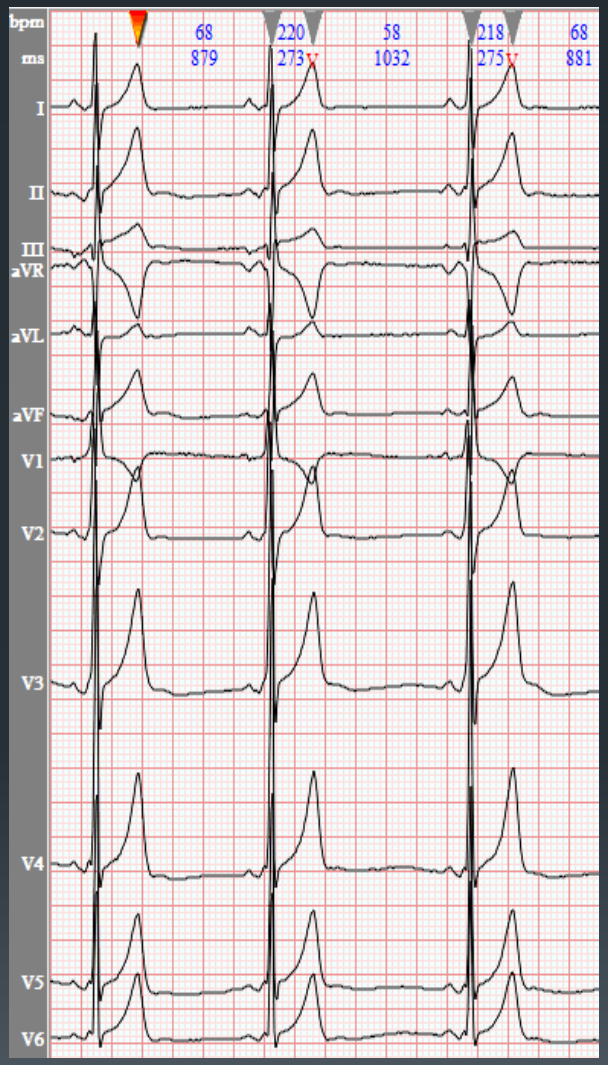
Male 28 years. Rugby player. Asymtomatic. QRS axis 179°, QRS 139 ms.

Complete Left bundle branch block. QRS≥120 ms

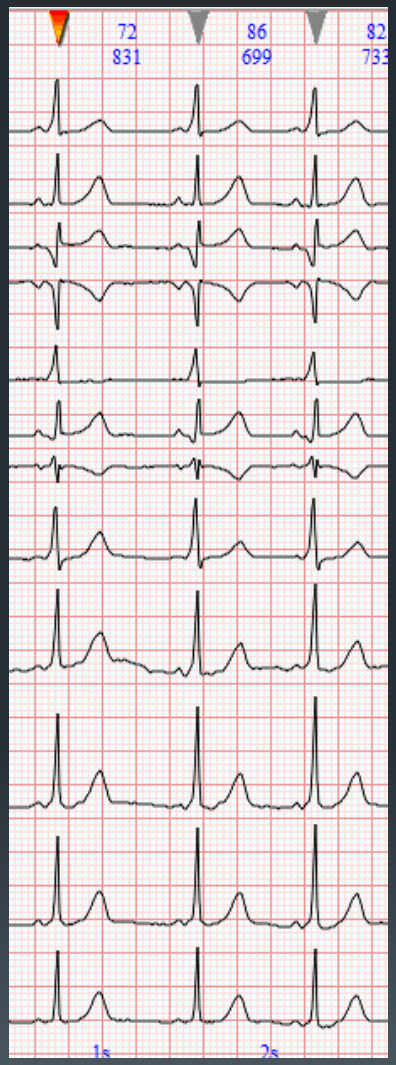


Male 38 years. Asintomatic. HTA (enalapril 10 mg c/12 hs). IMC 2,12. 2013
Irregular control de BP. New control 2014 and?

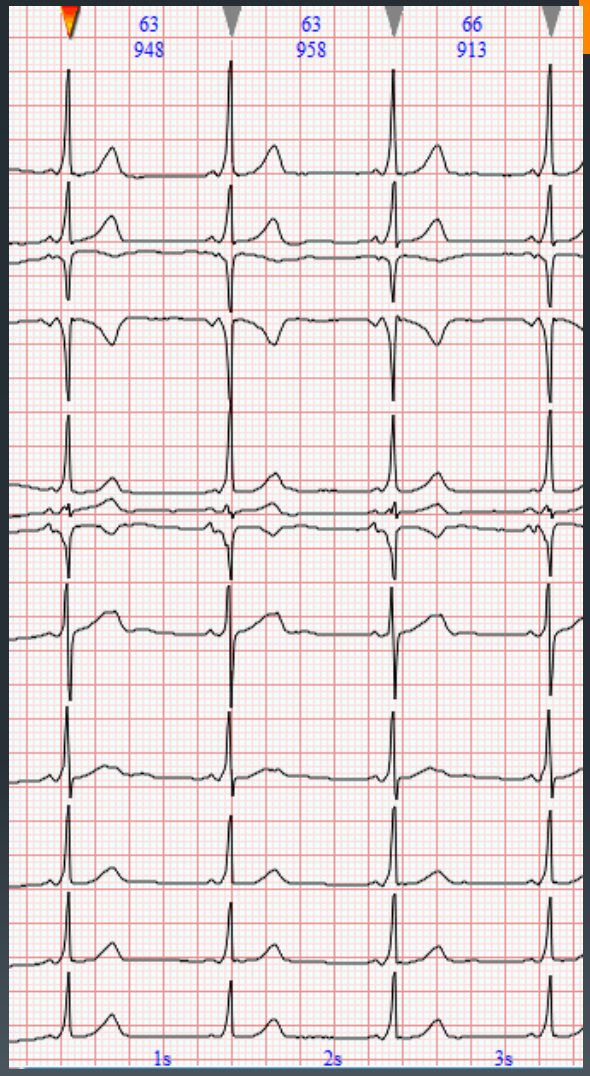
Ventricular pre-excitation



Male 14 years. Rugby. Asymtomatic

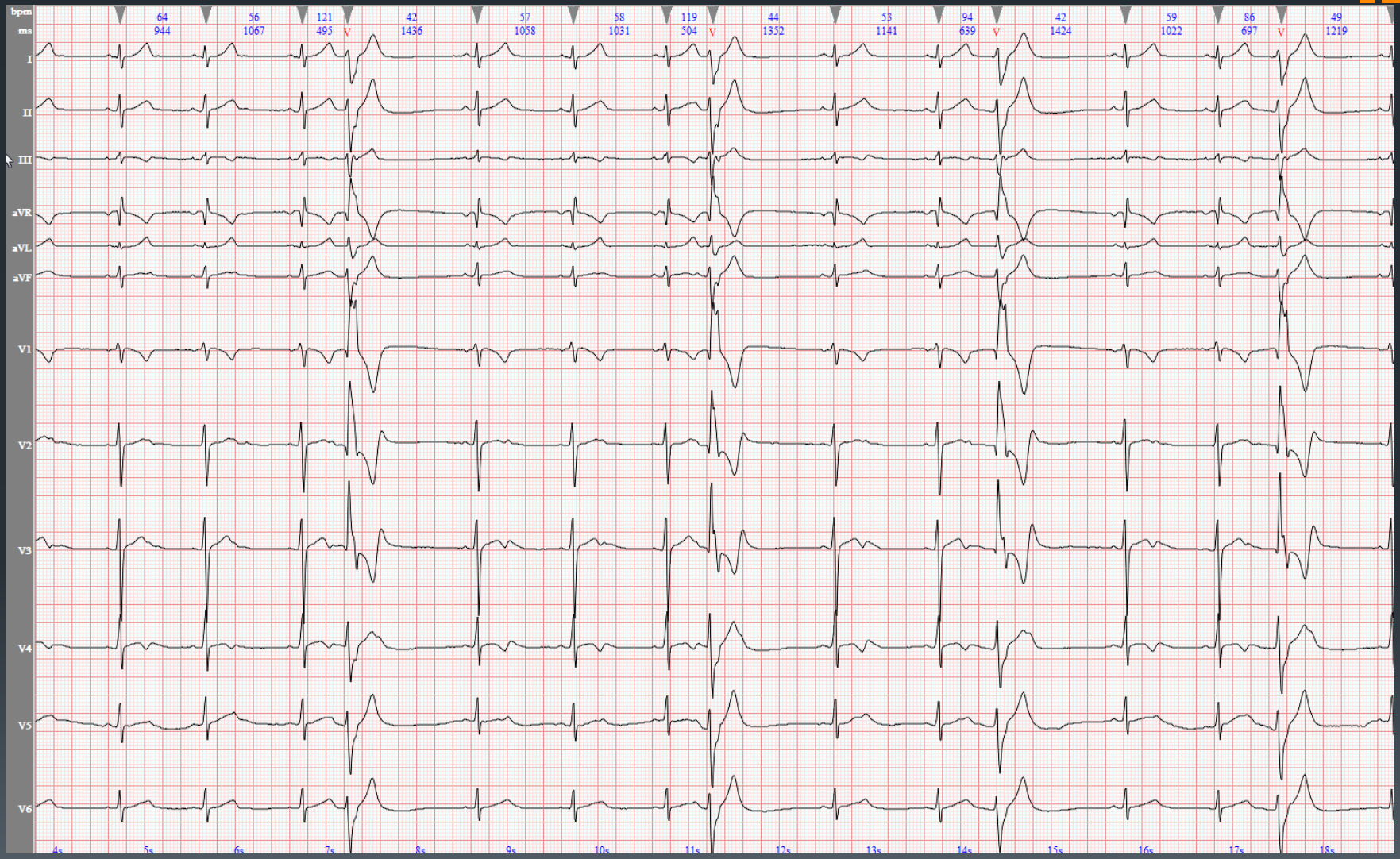


Female 14 years. Asymtomatic



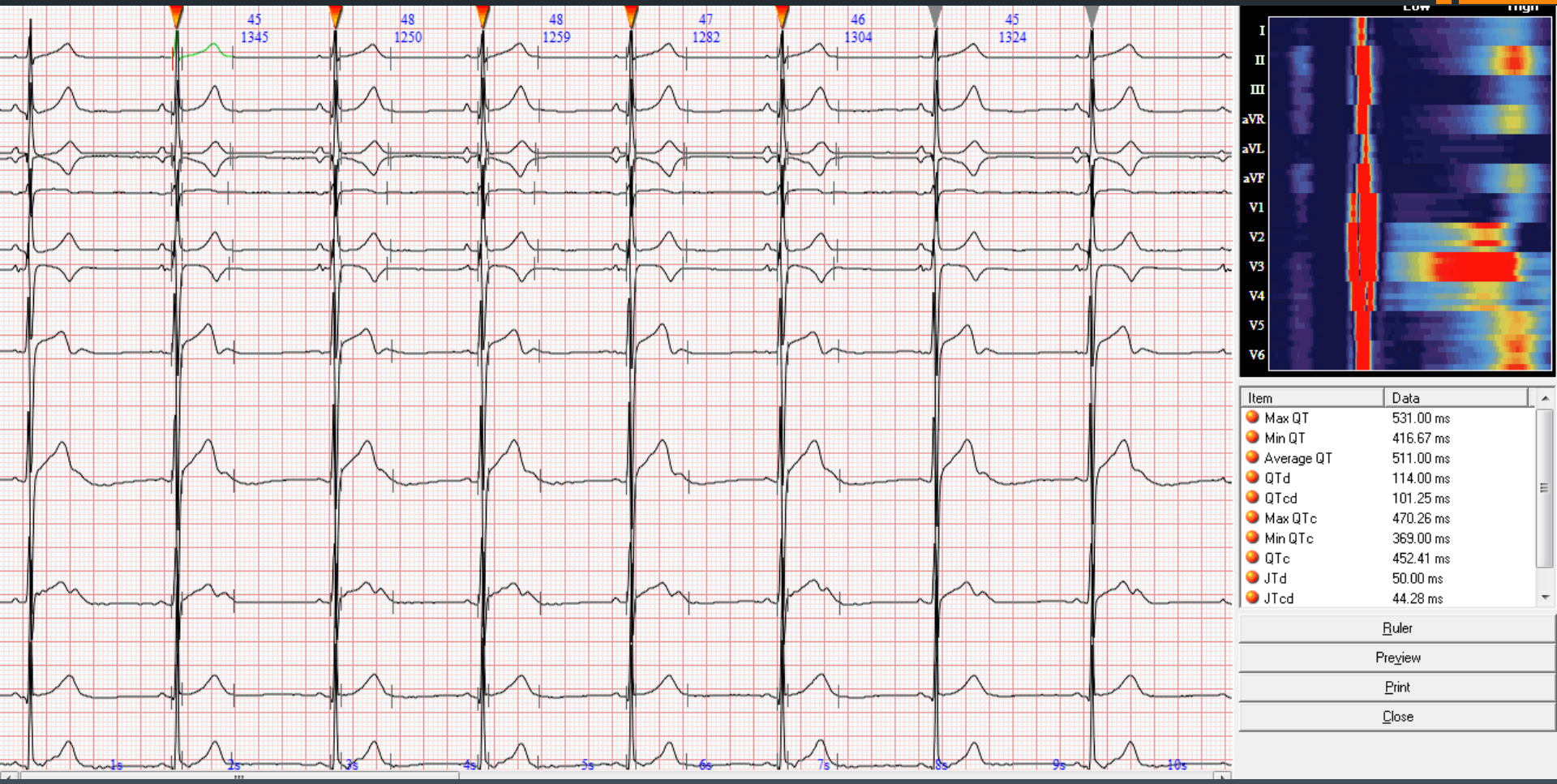
Male 12 years. Asymptomatic

Premature ventricular contractions ≥2 PVCs per 10 s tracing



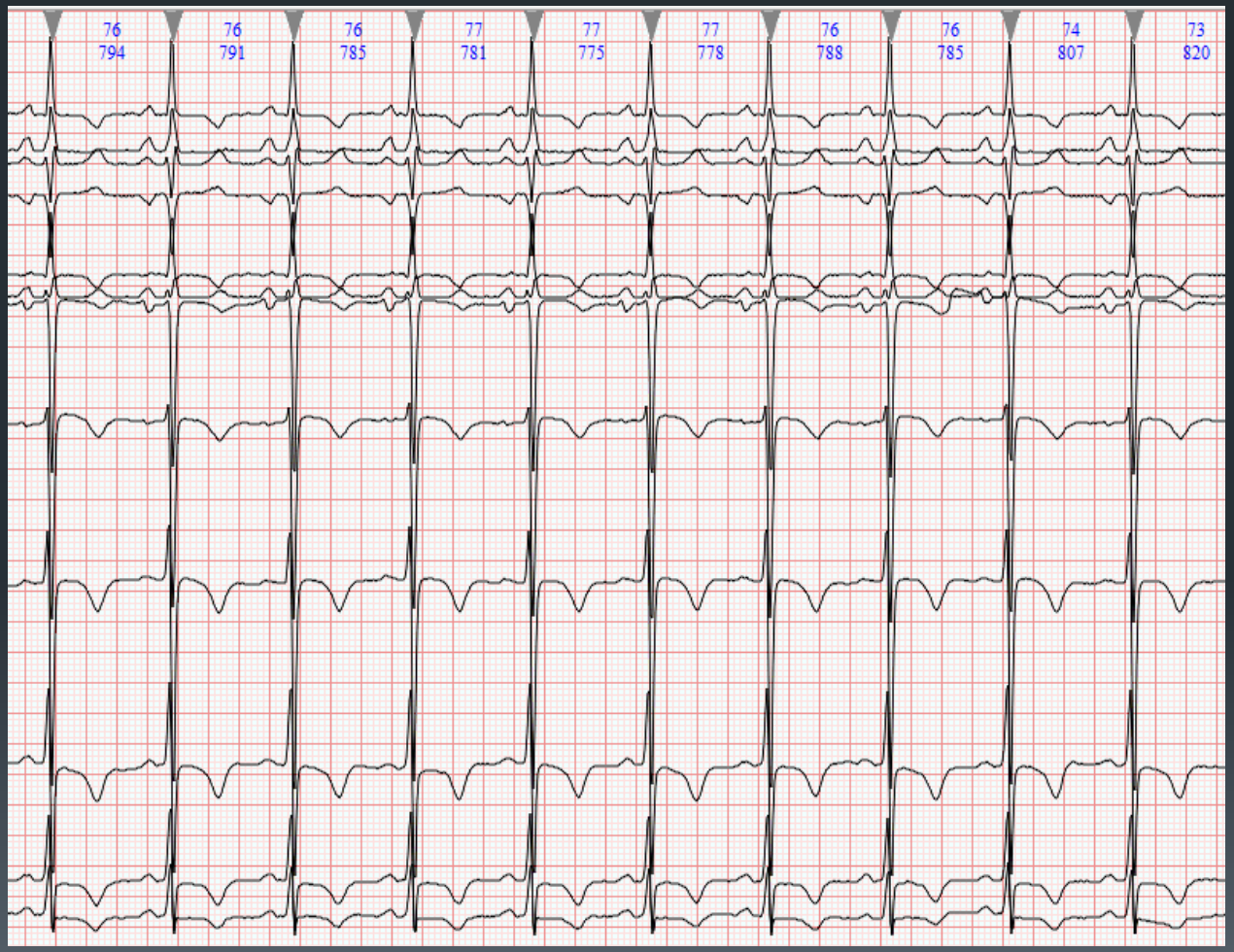
Male 16 years. PVC.

Long QT interval



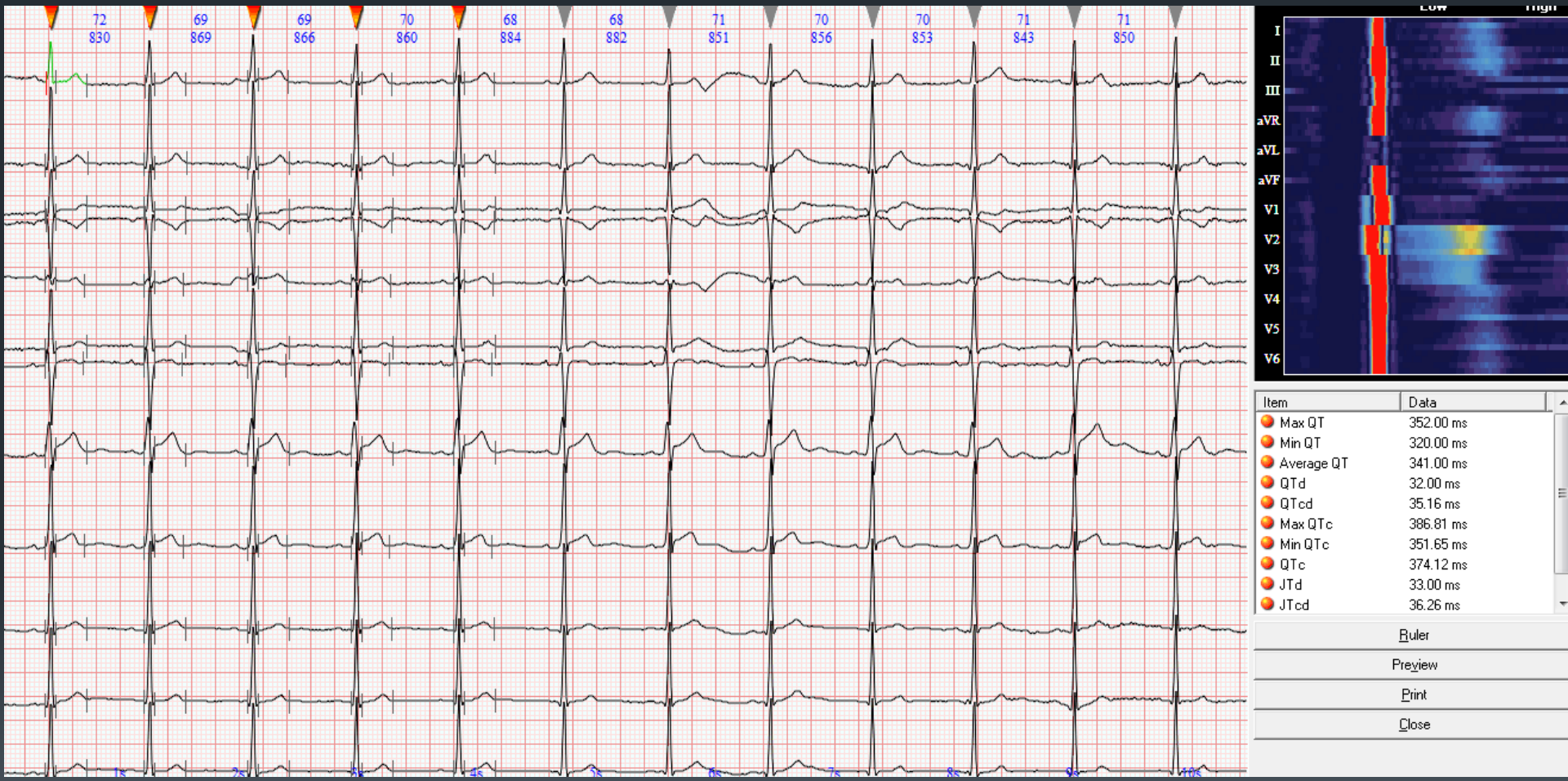
Male 16 years. Hockey. QTC 452 ms.
Normal in male 470 ms

Cadiomyopathyes

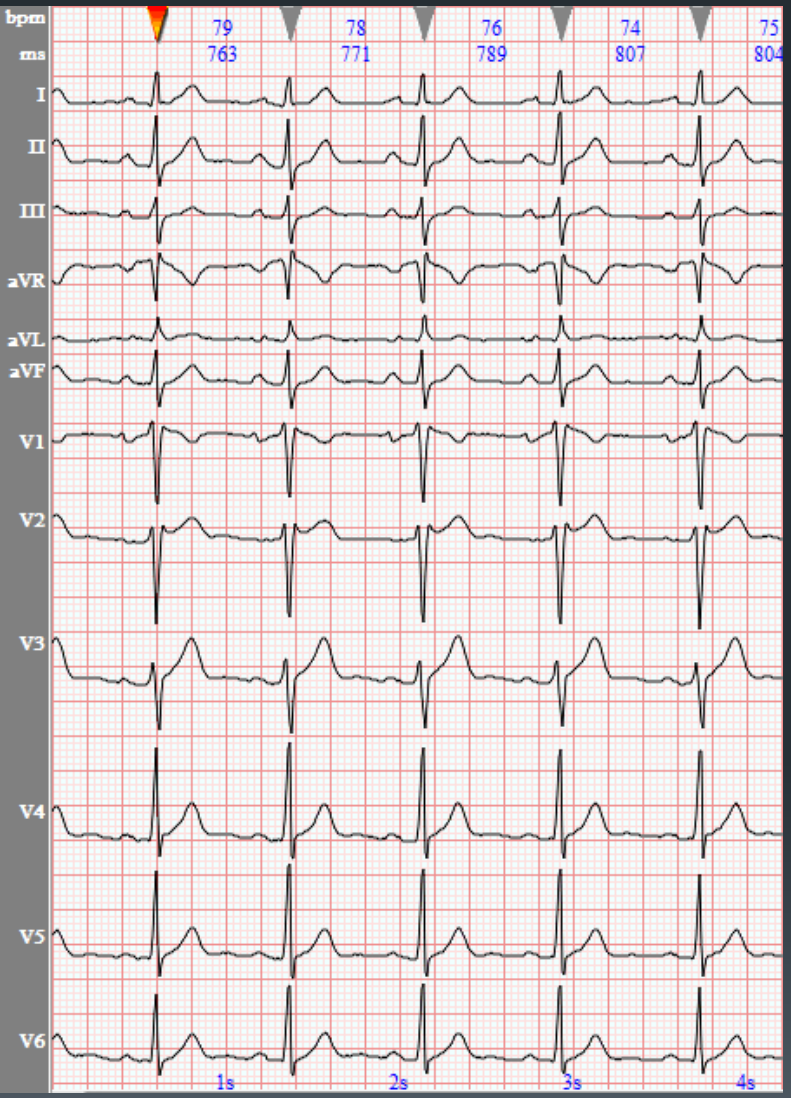


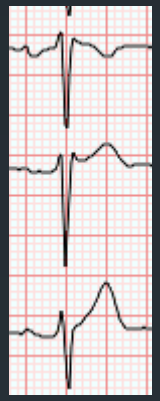
34 años con miocardiopatía dilatada, onda T invertidas y QTc 513 mseg

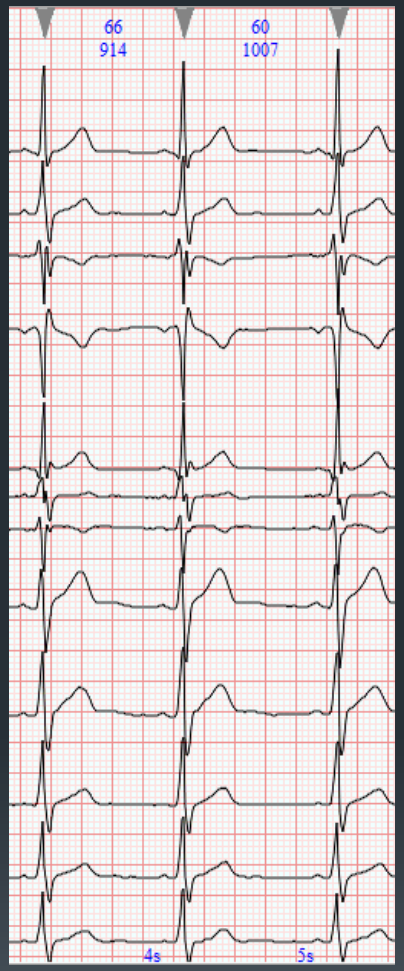
Short QT interval



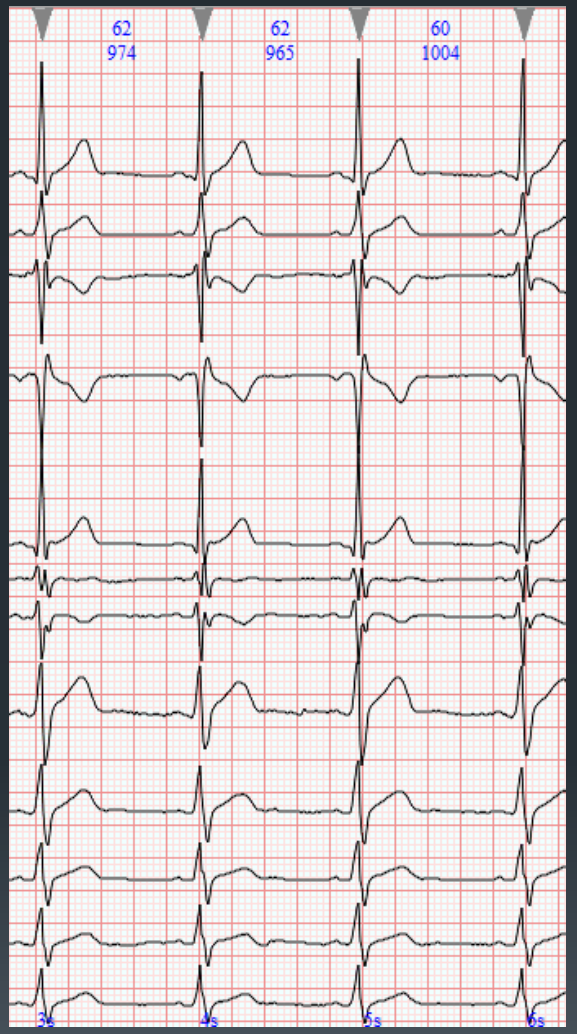
Male 14 years. Rugby. QTC 374 ms.
Short QR <329 ms


bpm
ms
79
763
78
771
76
789
74
807
75
804
I
II
III
aVR
aVL
aVF
V1
V2
V3
V4
V5
V6
1s
2s
3s
4s



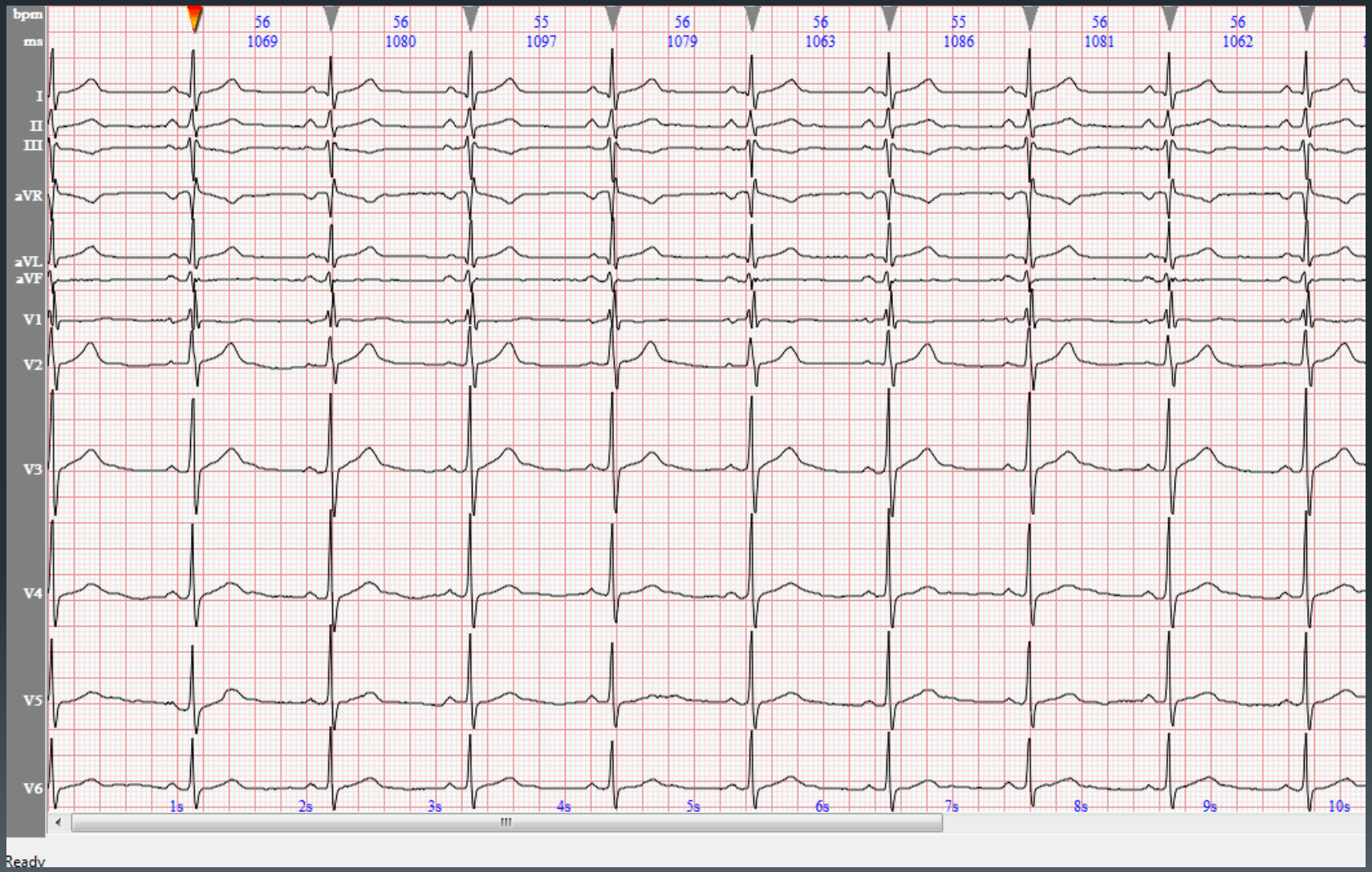


Male. 14 y. Asymtomatic. 2011



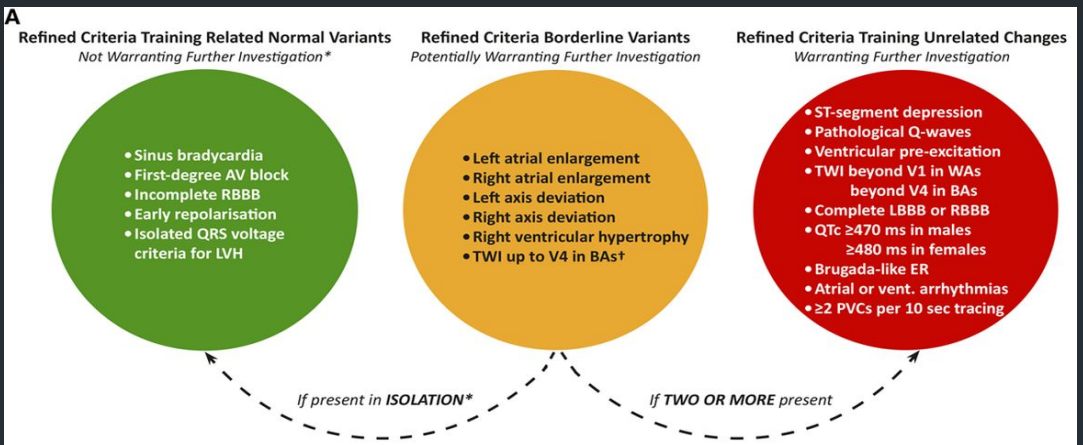
Male 18 y. 2015

And long time?



The definition of an abnormal ECG using the (A) refined criteria, (B) European Society of Cardiology (ESC) recommendations, and (C) Seattle criteria.

A



B

ESC Group 1 Training Related Changes
• Sinus bradycardia
• First-degree AV block
• Incomplete RBBB
• Early repolarisation
• Isolated QRS voltage criteria for LVH

ESC Group 2 Training Unrelated Changes	
• T-wave inversion	• Ventricular pre-excitation
• ST-segment depression	• Complete LBBB or RBBB
• Pathological Q-waves	• Long QT >440 ms in males
• Left or right atrial enlargement	• Long QT>460 ms in females
• Left axis deviation / left anterior hemiblock	• Short QT interval <380 ms
• Right axis deviation / left posterior hemiblock	• Brugada-like ER
• Right ventricular hypertrophy	• Atrial/ventricular arrhythmias

C

Seattle Criteria Abnormal Findings in Athletes		
• T-wave inversion beyond V2 in WAs and V4 in BAs†	• Left atrial enlargement	• Short-QT interval ≤320 ms
• ST-segment depression	• Right atrial enlargement	• Brugada-like ECG pattern
• Pathological Q-waves	• Right ventricular hypertrophy pattern	• Profound sinus bradycardia (<30 bpm)
• Complete left bundle branch block	• Ventricular pre-excitation	• Atrial tachyarrhythmias
• Intraventricular conduction delay *(any QRS ≥140 ms)*	• Long-QT interval ≥470 ms in males	• Premature ventricular contractions
• Left axis deviation	• Long-QT interval ≥480 ms in females	• Ventricular arrhythmias

KEY

AV:	Atrioventricular	ESC:	European Society of Cardiology	PVCs:	Premature ventricular complexes	TWI:	T-wave Inversion
BAs:	Black athletes	LBBB:	Left bundle branch block	RBBB:	Right bundle branch block	Vent.:	Ventricular
ER:	Early repolarisation	LVH:	Left ventricular hypertrophy	Sec:	Second	WAs:	White athletes

**In otherwise asymptomatic athletes with no family history or abnormal examination findings. †When preceded by characteristic convex ST-segment elevation.*

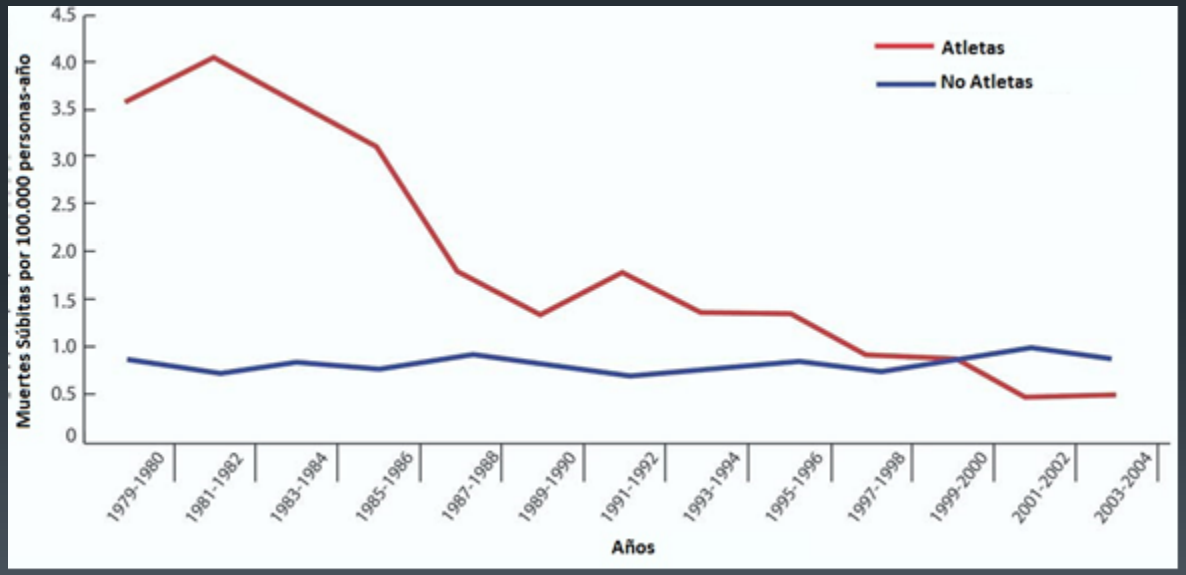
Nabeel Sheikh et al. Circulation. 2014;129:1637-1649

Comparison of Electrocardiographic Criteria for the Detection of Cardiac Abnormalities in Elite Black and White Athletes CLINICAL PERSPECTIVE

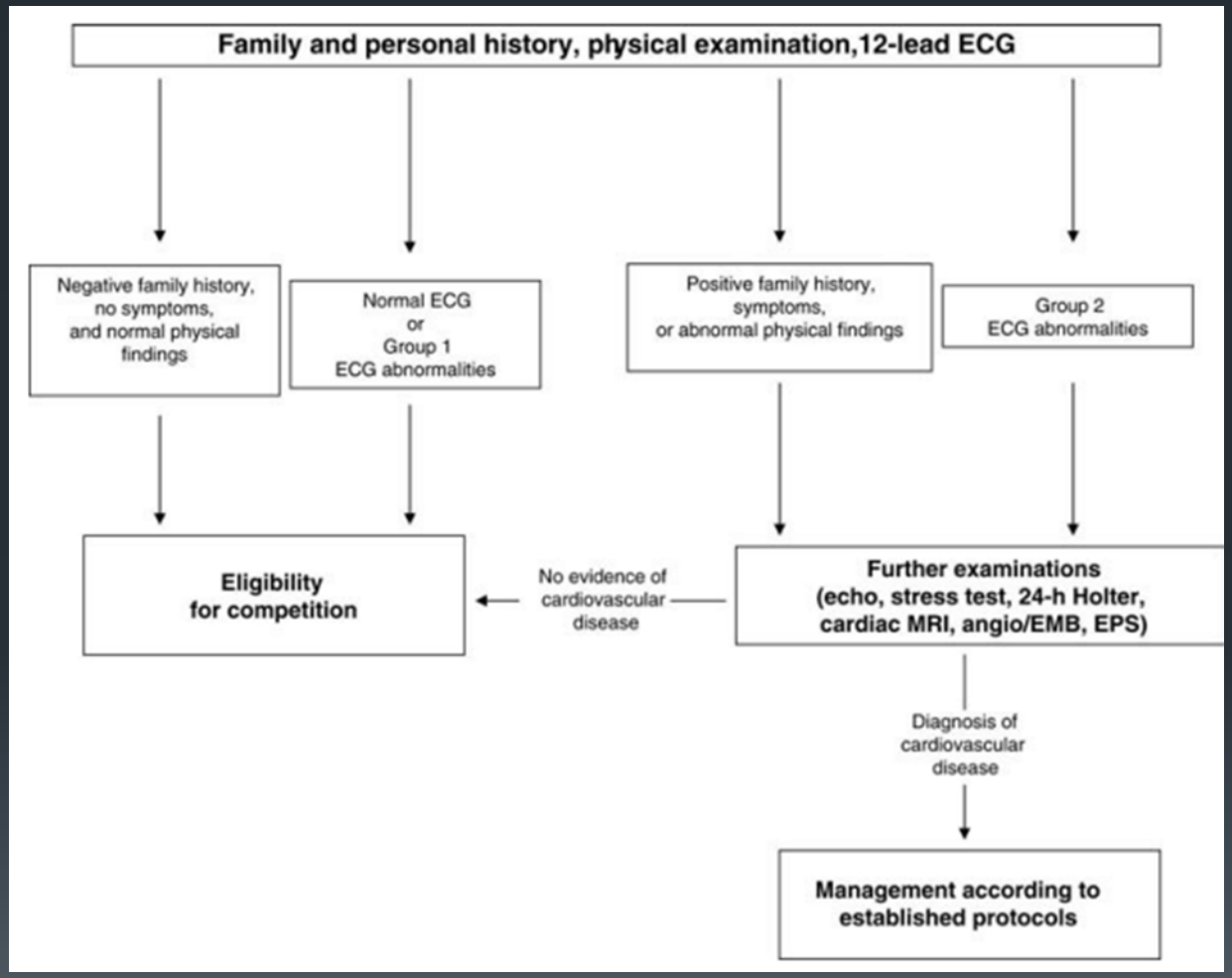
ECG Parameters Used to Define Various ECG Abnormalities in the European Society of Cardiology Recommendations, Seattle Criteria, and Refined Criteria

ECG Abnormality	ESC Recommendations	Seattle Criteria
Left atrial enlargement	Negative portion of the P wave in lead V1 ≥0.1 mV in depth and ≥40 ms in duration	Prolonged P wave duration of >120 ms in lead I or II with negative portion of the P wave ≥1 mm in depth and ≥40 ms in duration in lead
Right atrial enlargement	P-wave amplitude ≥2.5 mm in lead II, III, or aVF	As ESC
Left QRS axis deviation	−30° to −90°	As ESC
Right QRS axis deviation	>115°	>120°
Right ventricular hypertrophy	Sum of R wave in V1 and S wave in V5 or V6 ≥10.5 mm	Sum of R wave in V1 and S wave in V5 >10.5 mm and right axis deviation >120°
Complete LBBB	QRS ≥120 ms, predominantly negative QRS complex in lead V1 (QS or rS), and upright monophasic R wave in leads I and V6	As ESC
Complete RBBB	RSR′ pattern in anterior precordial leads with QRS duration ≥120 ms	Not relevant
Intraventricular conduction delay	Any QRS duration >120 ms including RBBB and LBBB	Any QRS duration ≥140 ms or complete LBBB
Pathological Q-wave	>4 mm deep in any lead except III, aVR	>3 mm deep or >40 ms duration in ≥2 leads except III and aVR
Significant T-wave inversion	≥2 mm in ≥2 adjacent leads (deep) or “minor” in ≥2 leads	>1 mm in depth in ≥2 leads V2−V6, II and aVF, or I and aVL (excludes III, aVR, and V1)
ST-segment depression	≥0.5 mm deep in ≥2 leads	As ESC
Ventricular preexcitation	PR interval <120 ms with or without delta wave	PR interval <120 ms with delta wave

Trends in Sudden Cardiovascular Death in Young Competitive Athletes After Implementation of a Preparticipation Screening Program



Recommendations for interpretation of 12-lead electrocardiogram in the athlete



Domenico Corrado1*, Antonio Pelliccia2 . European Heart Journal (2010) 31, 243–259

Bethesda Conference #36 and the European Society of Cardiology Consensus Recommendations Revisited

A Comparison of U.S. and European Criteria for Eligibility and Disqualification of Competitive Athletes With Cardiovascular Abnormalities

36th Bethesda Conference: eligibility recommendations for competitive athletes with cardiovascular abnormalities. J Am Coll Cardiol 2005;45:2– 64

Recommendations for competitive sports participation in athletes with cardiovascular disease.
A consensus document from the Study Group of Sports Cardiology of the Working Group of Cardiac Rehabilitation and Exercise Physiology, and the Working Group of Myocardial and Pericardial diseases of the European Society of Cardiology. Eur Heart J 2005;26:1422– 45.

Mandatory reporting systems for SDs in young people (including athletes) do not exist in the countries, analyses of event frequency, are usually highly dependent on accounts in the public record, from the Internet, or from personal communications for the identification of events that provide important epidemiological and clinical information.

Thank you
Obrigado
Muchas gracias