CENTER FOR SPORTS CARDIOLOGY

The Heart of the Matter

Interpreting the Athlete's ECG
Implications of COVID-19 for Athletes

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SASMA

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South African Sports Medicine Association

20 - 22 October 2015

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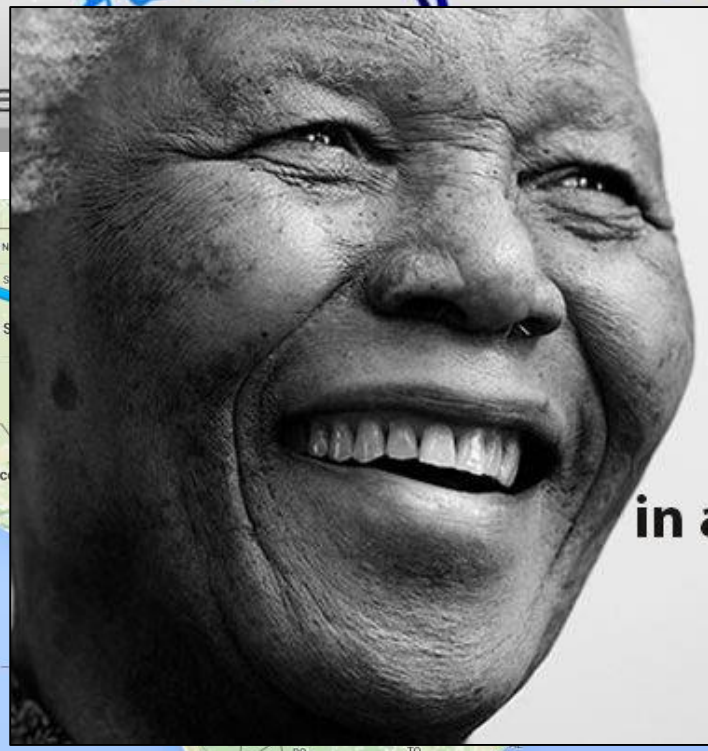


**Sport has the power
to change the world.
It has the power
to inspire.
It has the power
to unite people
in a way that little else does.**

- Nelson Mandela

Teamwork & Collaboration

Sudden Cardiac Death in Athletes

- **75% of all fatalities** during sports are cardiovascular related
- Effective prevention requires **early detection** of cardiac disorders predisposing to SCD

Why ECG?

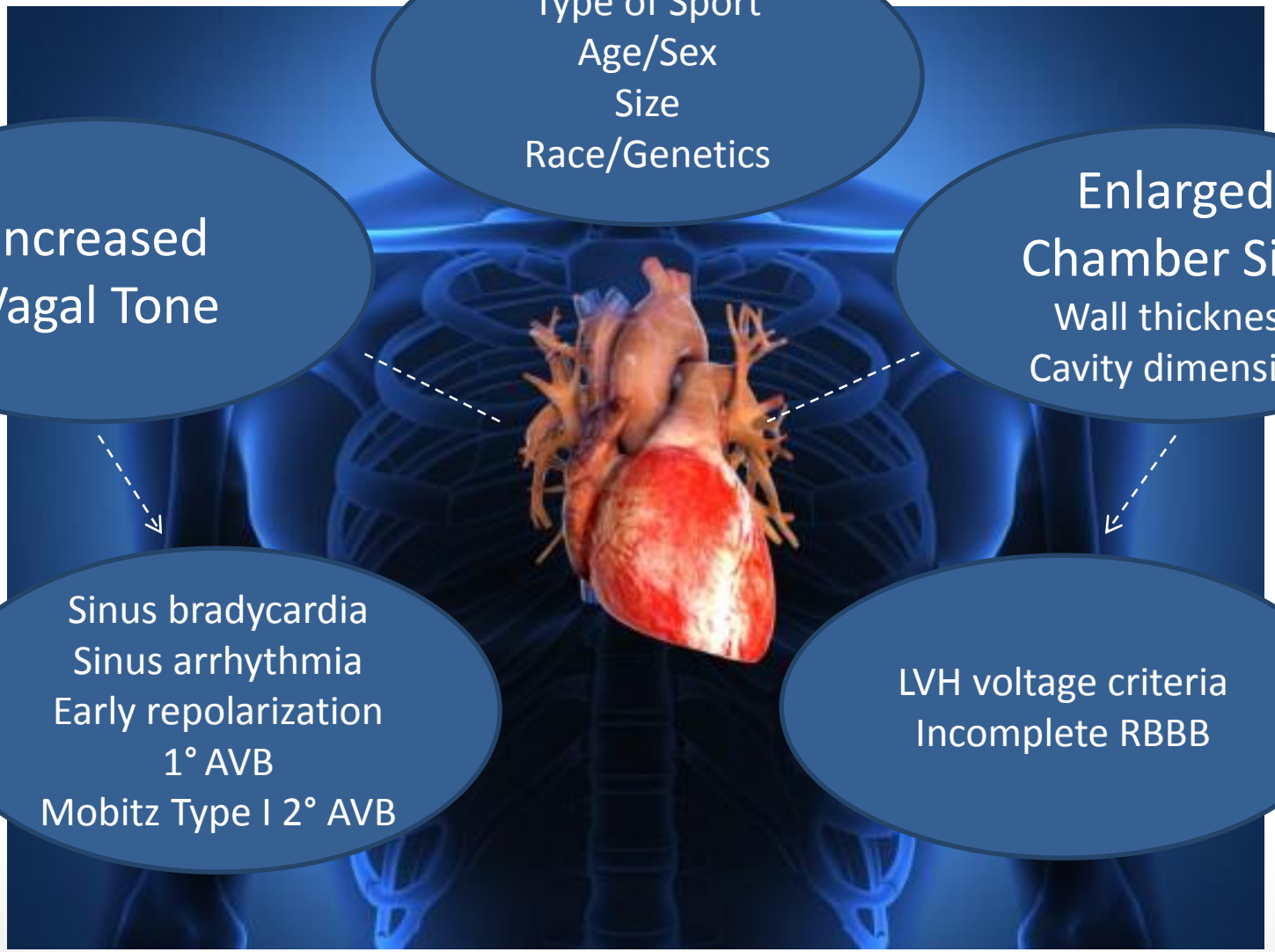
Diagnostic	Screening
Symptoms	Cardiomyopathy
Abnormal physical exam	Ion channel disorders
Family history	Pre-excitation

- Accurate ECG interpretation requires:
  1. Knowledge of the physiological adaptations in athlete's heart
  2. Understanding of ECG abnormalities suggestive of a pathological disorder
  3. Proper secondary investigation of an abnormal ECG
  4. Training and experience
  5. Cardiology resources

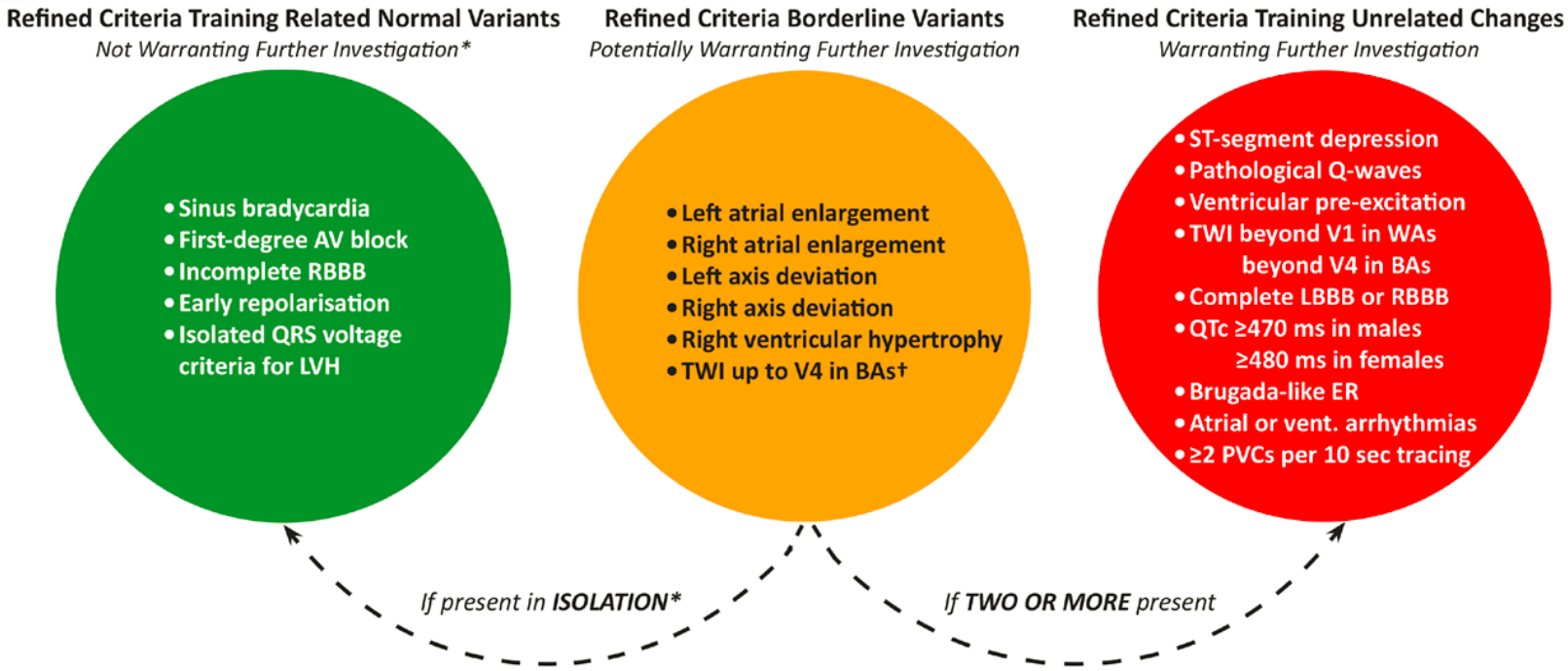
Outline

- Evolution of ECG interpretation standards
- **International Criteria**
- **6-steps to ECG interpretation in athletes**
- Examples!
- Cardiac considerations in **COVID-19**
- ECG training resources

Physiologic Cardiac Adaptation: 'Athlete's Heart'



Evolution of ECG Interpretation in Athletes



Epidemiology and Prevention

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

Nabeel Sheikh, MRCP; Michael Papadakis, MRCP; Saqib Ghani, MRCP; Abbas Zaidi, MRCP; Sabiha Gati, MRCP; Paolo Emilio Adami, MD; François Carré, PhD; Frédéric Schnell, PhD; Mathew Wilson, PhD; Paloma Avila, MD; William McKenna, MD, DSc, FESC; Sanjay Sharma, MD, FRCP, FESC (UK)

2014

2nd International Summit on ECG Interpretation in Athletes

February 26-27, 2015 – Seattle, WA

European Heart Journal (2017) **00**, 1–19
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CURRENT OPINION

International recommendations for electrocardiographic interpretation in athletes

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Eugene H. Chung[11], Michael S. Emery[12], Victo
Carmen Adamuz[4], Chad A. Asplund[16], Gordo
Joseph C. Marek[18], Silvana Molossi[19], Josef Nie
Marco V. Perez[21], Nathan R. Riding[4], Tess Saa
David M. Shipon[24], Ricardo Stein[25], Victoria L
Domenico Corrado[28]

2017

International Recommendations for Electrocardiographic Interpretation in Athletes

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International criteria for electrocardiographic interpretation in athletes

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Joseph C Marek,[23] Silvana Molossi,[24,25] Josef Niebauer,[26] Hank F Pelto,[1]
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This statement has been endorsed by the following societies: American Medical Society for Sports Medicine (AMSSM), Austrian Society of Sports Medicine and Prevention, Brazilian Society of Cardiology – Department of Exercise and Rehabilitation (SBC – DERC), British Association for Sports and Exercise Medicine (BASEM), Canadian Academy of Sport and Exercise Medicine (CASEM), European College of Sports and Exercise Physicians (ECOSEP), European Society of Cardiology (ESC) Section of Sports Cardiology, Fédération Internationale de Football Association (FIFA), German Society of Sports Medicine and Prevention, International Olympic Committee (IOC), Norwegian Association of Sports Medicine and Physical Activity (NIMF), South African Sports Medicine Association (SASMA), Spanish Society of Cardiology (SEC) Sports Cardiology Group, Sports Doctors Australia, and the Swedish Society of Exercise and Sports Medicine (SFAIM). The American College of Cardiology (ACC) affirms the value of this document. ACC supports the general principles in the document and believes it is of general benefit to its membership.

Freely available at: http://bjsm.bmj.com/content/early/2017/03/03/bjsports-2016-097331

‘International Criteria’

1. **Update ECG interpretation standards** based on new and emerging research
2. **Develop clear guide to the appropriate evaluation of ECG abnormalities** for conditions associated with SCD in athletes

International Criteria for ECG Interpretation in Athletes

Normal ECG Findings

- Increased QRS voltage for LVH or RVH
- Incomplete RBBB
- Early repolarization/ST segment elevation
- ST elevation followed by T wave inversion V1-V4 in black athletes
- T wave inversion V1-V3 ≤ age 16 years old
- Sinus bradycardia or arrhythmia
- Ectopic atrial or junctional rhythm
- 1° AV block
- Mobitz Type I 2° AV block

Borderline ECG Findings

- Left axis deviation
- Left atrial enlargement
- Right axis deviation
- Right atrial enlargement
- Complete RBBB

Abnormal ECG Findings

- T wave inversion
- ST segment depression
- Pathologic Q waves
- Complete LBBB
- QRS ≥ 140 ms duration
- Epsilon wave
- Ventricular pre-excitation
- Prolonged QT interval
- Brugada Type 1 pattern
- Profound sinus bradycardia < 30 bpm
- PR interval ≥ 400 ms
- Mobitz Type II 2° AV block
- 3° AV block
- ≥ 2 PVCs
- Atrial tachyarrhythmias
- Ventricular arrhythmias

In isolation

2 or more

No further evaluation required in asymptomatic athletes with no family history of inherited cardiac disease or SCD

Further evaluation required to investigate for pathologic cardiovascular disorders associated with SCD in athletes

Key Changes: Seattle Criteria to the International Criteria

1. ECG guidelines for athletes age 12-16 years and recognition of juvenile T wave inversion as normal
2. Introduction of a “yellow” list or borderline findings (RBBB, axis deviation, atrial enlargement) in which ≥2 require more evaluation
3. New definition for pathologic Q waves
4. TWI ≥1 mm in V5 or V6 alone warrants more investigation
5. Epsilon wave added to “red” list
6. Findings that might warrant evaluation for coronary artery disease in athletes ≥30 years
7. Recommendations for secondary testing

Does modifying the criteria come with a cost?

Do we sacrifice sensitivity to improve specificity?

The Seattle Criteria increase the specificity of preparticipation ECG screening among elite athletes

Maria Brosnan,[1,
Andrew MacIsaac

Comparison of three ECG criteria for athlete pre-participation screening

David Pickham, PhD, RN,[a,*] Shirin Zarafshar, MD,[a] Divya Sani,[b] Nikhil Kumar,[b]
[c]

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

Nabeel Sheikh, MRCP; Michael Papadakis, MRCP; Saqib Ghani, MRCP; Abbas Zaidi, Sabiha Gati, MRCP; Paolo Emilio Adami, MD; François Carré, PhD; Frédéric Schnel, Mathew Wilson, PhD; Paloma Avila, MD; William McKenna, MD, DSc, FESC

ORIGINAL RESEARCH

Five-Year Experience with Screening Electrocardiograms in National Collegiate Athletic Association Division I Athletes

Colin Fuller, MD, FACC, Carol Scott, MD,† Cheryl Hug-English, MD,†*

ORIGINAL ARTICLE

Comparison of three current sets of electrocardiographic interpretation criteria for use in screening athletes

Nathan R Riding,[1,2] Nabeel Sheikh,[3] Carmen Adamuz,[4] Victoria Watt,[4] Abdulaziz Farooq,[1] Gregory P Whyte,[2] Keith P George,[2] Jonathan A Drezner,[5] Sanjay Sharma,[3] Mathew G Wilson[1,4]

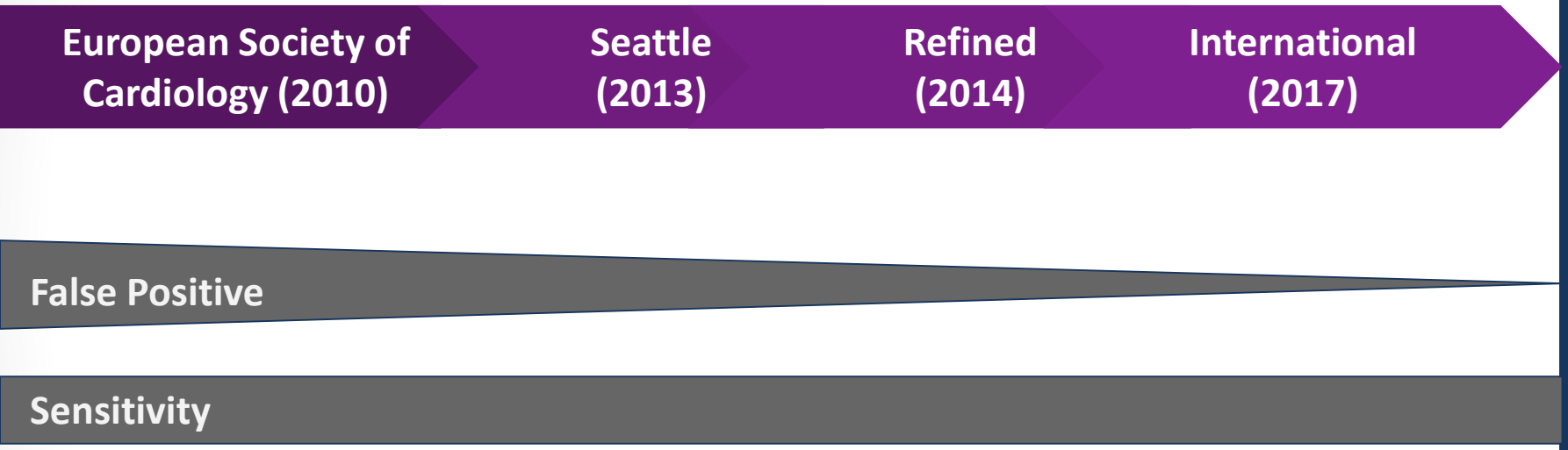
Accuracy of the ECG for differential diagnosis between hypertrophic cardiomyopathy and athlete's heart: comparison between the European Society of Cardiology (2010) and International (2017) criteria

Alessandro Zorzi,[1] Chiara Calore,[1] Riccardo Vio,[1] Antonio Pelliccia,[2] Domenico Corrado[1]

Prevalence and significance of T-wave inversion in Arab and Black paediatric athletes: Should anterior T-wave inversion interpretation be governed by biological or chronological age?

Gavin McClean, Nathan R Riding, Guido Pieles, Sanjay Sharma, Victoria Watt, Carmen Adamuz, Amanda Johnson, Antonio Tramullas, Keith P George, David Oxborough, Mathew G Wilson Show I

Evolution of ECG Interpretation Standards



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Electrocardiogram interpretation in NCAA athletes: Comparison of the 'Seattle' and 'International' criteria

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2019

International Criteria	Expert Over-read	Cardea
Total abnormal	1.6%	2.5%
False positive	1.3%	2.3%
Positive predictive value	1 in 6	1 in 10

Cardea 20/20

Clinical questions when interpreting an athlete's ECG

1. Is the ECG classified as:
   A. Normal – no further evaluation needed
   B. Abnormal – further evaluation needed

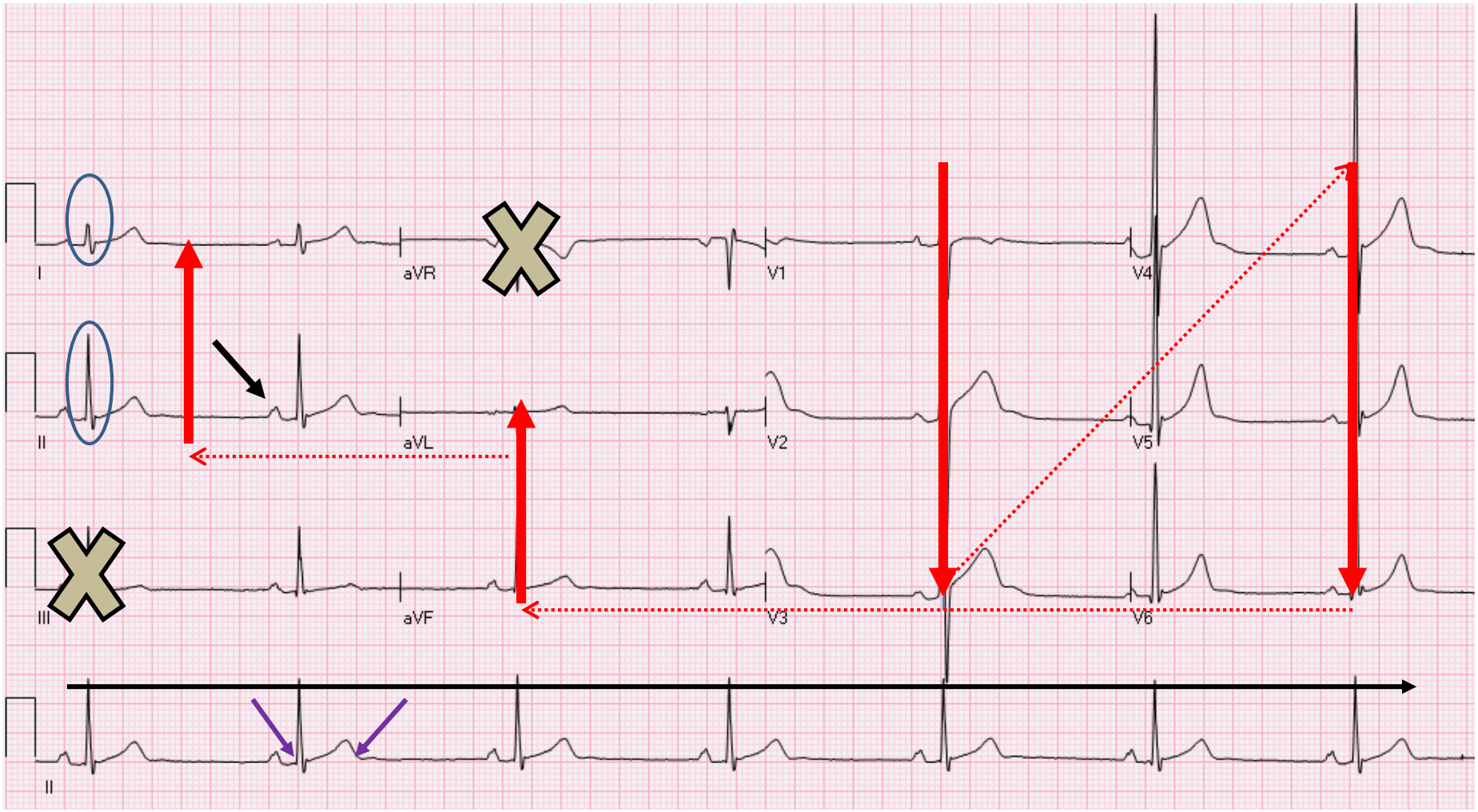
2. If the ECG is "abnormal":
   A. What is the specific ECG abnormality?
   B. What is the appropriate next step in the evaluation?

3. Relevant clinical information:
   A. Age, race, and sex of athlete
   B. Asymptomatic and no family history of inherited cardiac disease or SCD?

6-Steps to ECG Interpretation in Athletes

Where to look?	What to look for?
1. **Precordial** (V1-V6) then **limb leads** (aVF, aVL, II, I)	Q waves, ST depression, T wave inversion
2. **Precordial** (V1-V6) then **limb leads** (aVF, aVL, II, I)	QRS morphology: • pre-excitation (delta wave; short PR) • bundle branch block • conduction delay (QRS ≥140 ms) • Brugada type 1
3. **Axis** – limb leads I and II	QRS pos in I and II (leftward to -30^{o}) QRS neg in I and aVR, pos in II (rightward to 120^{o})
4. **Atrial enlargement** – P wave in lead II (if needed V1)	LAE: P >120 ms → neg P wave in V1 RAE: P >2.5 mm
5. **Rhythm strip** – lead II or V5	QRS after every P wave Narrow QRS vs PVCs
6. **QT interval** – lead II or V5	QTc ≥470 ms males or ≥480 ms females

6-Steps to ECG Interpretation in Athletes

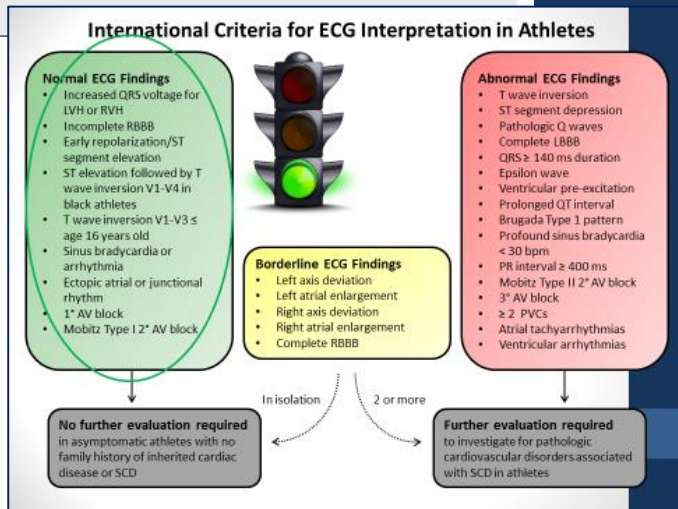


Definitions: Normal ECG Findings

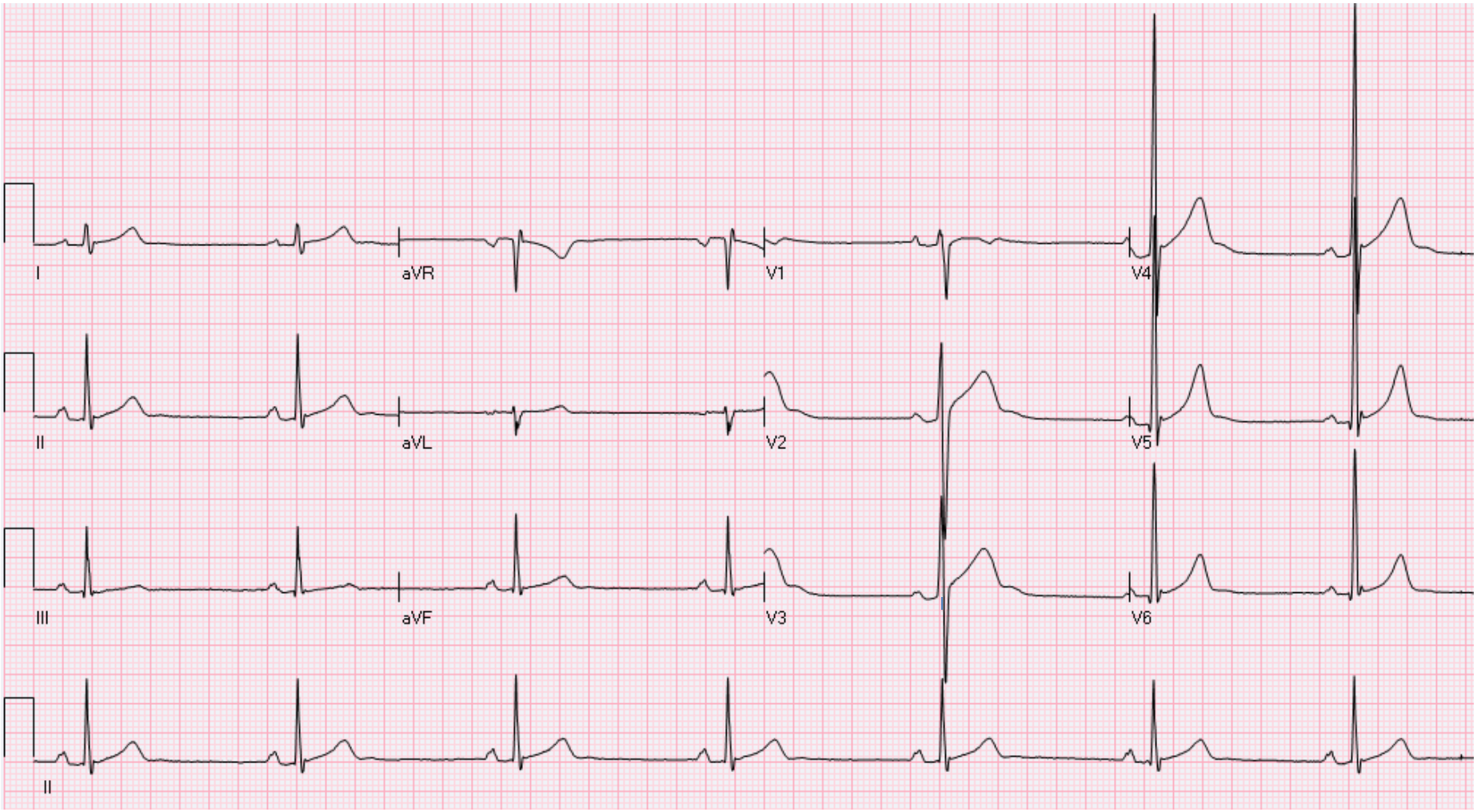
Normal ECG findings in athletes

These training-related ECG alterations are physiological adaptations to regular exercise, considered normal variants in athletes and do not require further evaluation in asymptomatic athletes with no significant family history.

Normal ECG finding	Definition
Increased QRS voltage	Isolated QRS voltage criteria for left (SV1 + RV5 or RV6 >3.5 mV) or right ventricular hypertrophy (RV1 + SV5 or SV6 >1.1 mV)
Incomplete right bundle branch block	rSR′ pattern in lead V1 and a qRS pattern in lead V6 with QRS duration <120 ms
Early repolarisation	J point elevation, ST elevation, J waves or terminal QRS slurring in the inferior and/or lateral leads
Black athlete repolarisation variant	J-point elevation and convex ('domed') ST segment elevation followed by T wave inversion in leads V1-V4 in black athletes
Juvenile T wave pattern	T wave inversion V1-V3 in athletes less than age less than 16
Sinus bradycardia	≥30 bpm
Sinus arrhythmia	Heart rate variation with respiration: rate increases during inspiration and decreases during expiration
Ectopic atrial rhythm	P waves are a different morphology compared with the sinus P wave, such as negative P waves in the inferior leads ('low atrial rhythm')
Junctional escape rhythm	QRS rate is faster than the resting P wave or sinus rate and typically less than 100 beats/min with narrow QRS complex unless the baseline QRS is conducted with aberrancy
1° atrioventricular block	PR interval 200–400 ms
Mobitz type I (Wenckebach) 2° atrioventricular block	PR interval progressively lengthens until there is a non-conducted P wave with no QRS complex; the first PR interval after the dropped beat is shorter than the last conducted PR interval

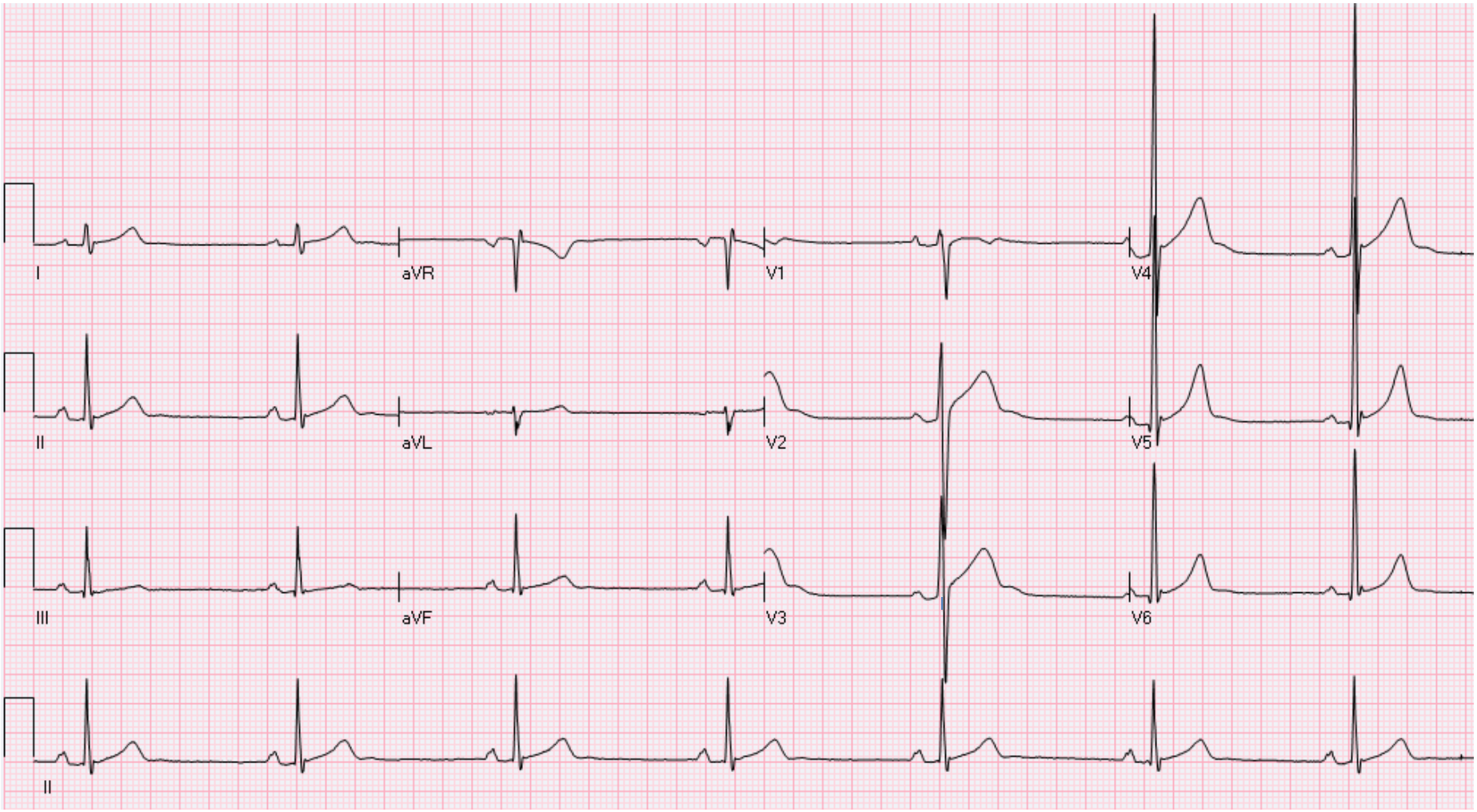


Step-1: ECG Interpretation in Athletes



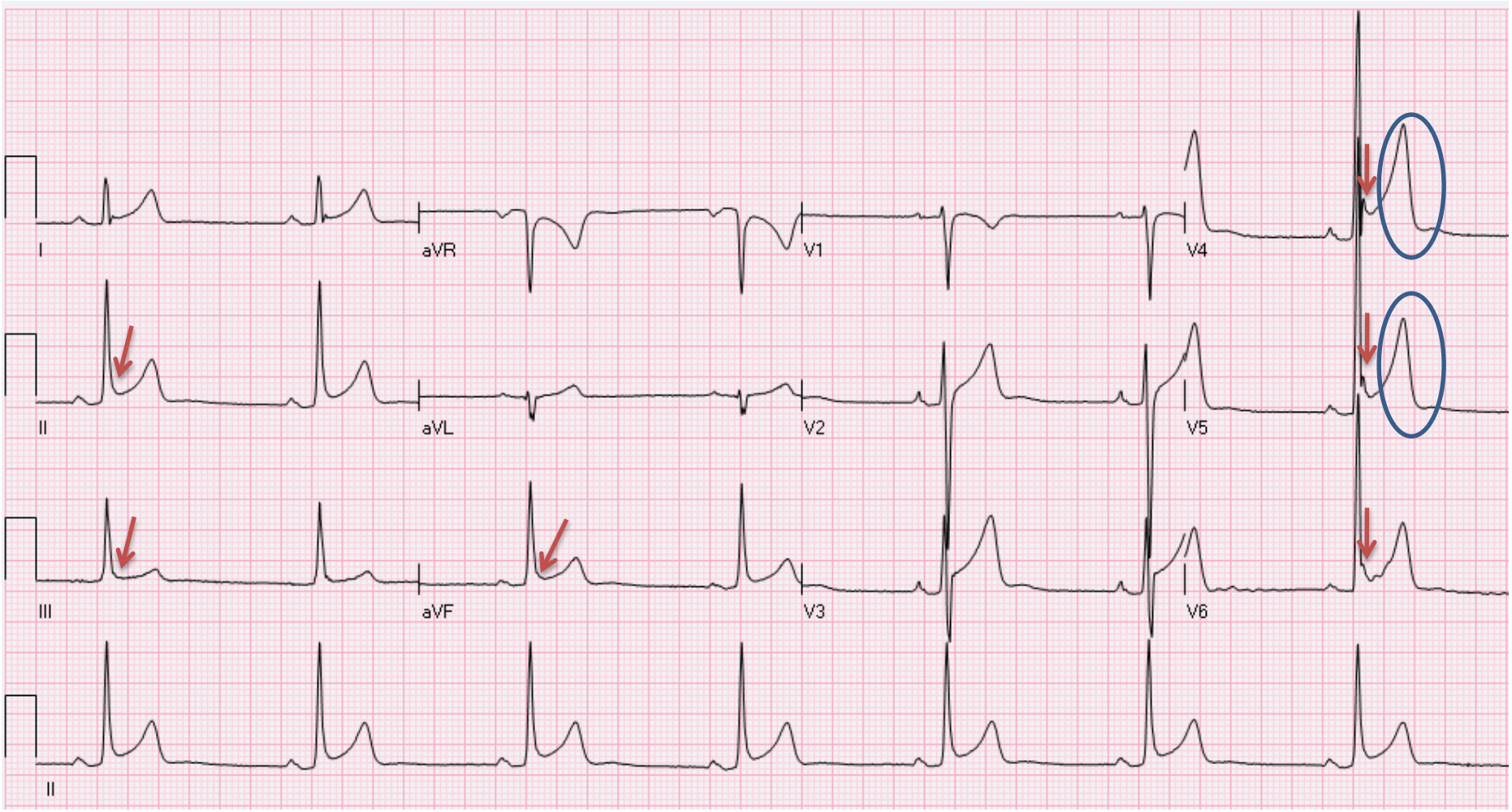
Where to look?	What to look for?
1. Precordial (V1-V6) then limb leads (aVF, aVL, II, I)	Q waves, ST depression, T wave inversion

Isolated Increased QRS Voltage



ECG from a 19 year old asymptomatic soccer player demonstrating voltage criteria for LVH (S-V1 + R-V5 > 35 mm). Note the absence of ST depression, T wave inversion, or pathologic Q waves. Increased QRS amplitude without other ECG abnormalities is a common finding in trained athletes and does not require additional testing.

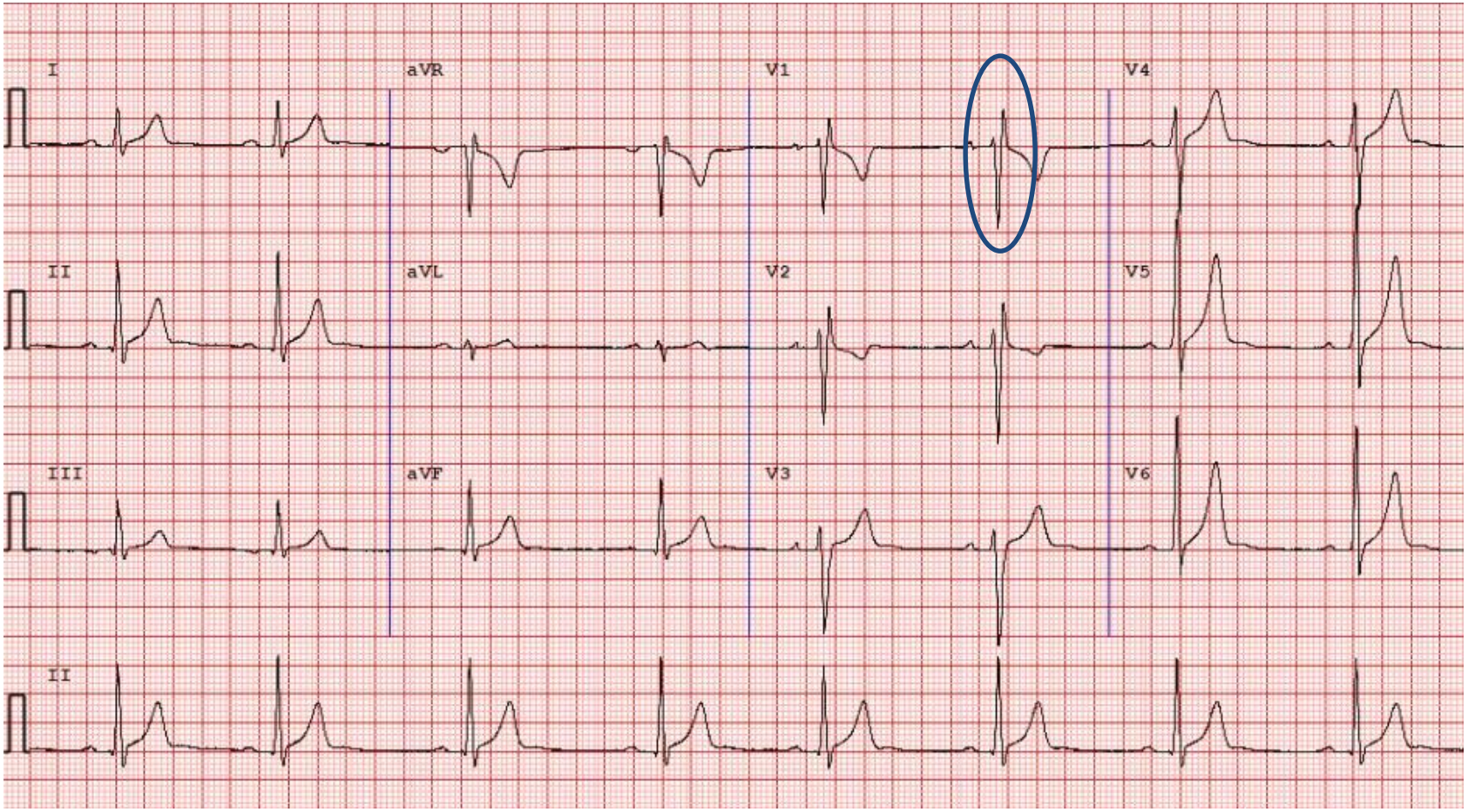
Early Repolarization



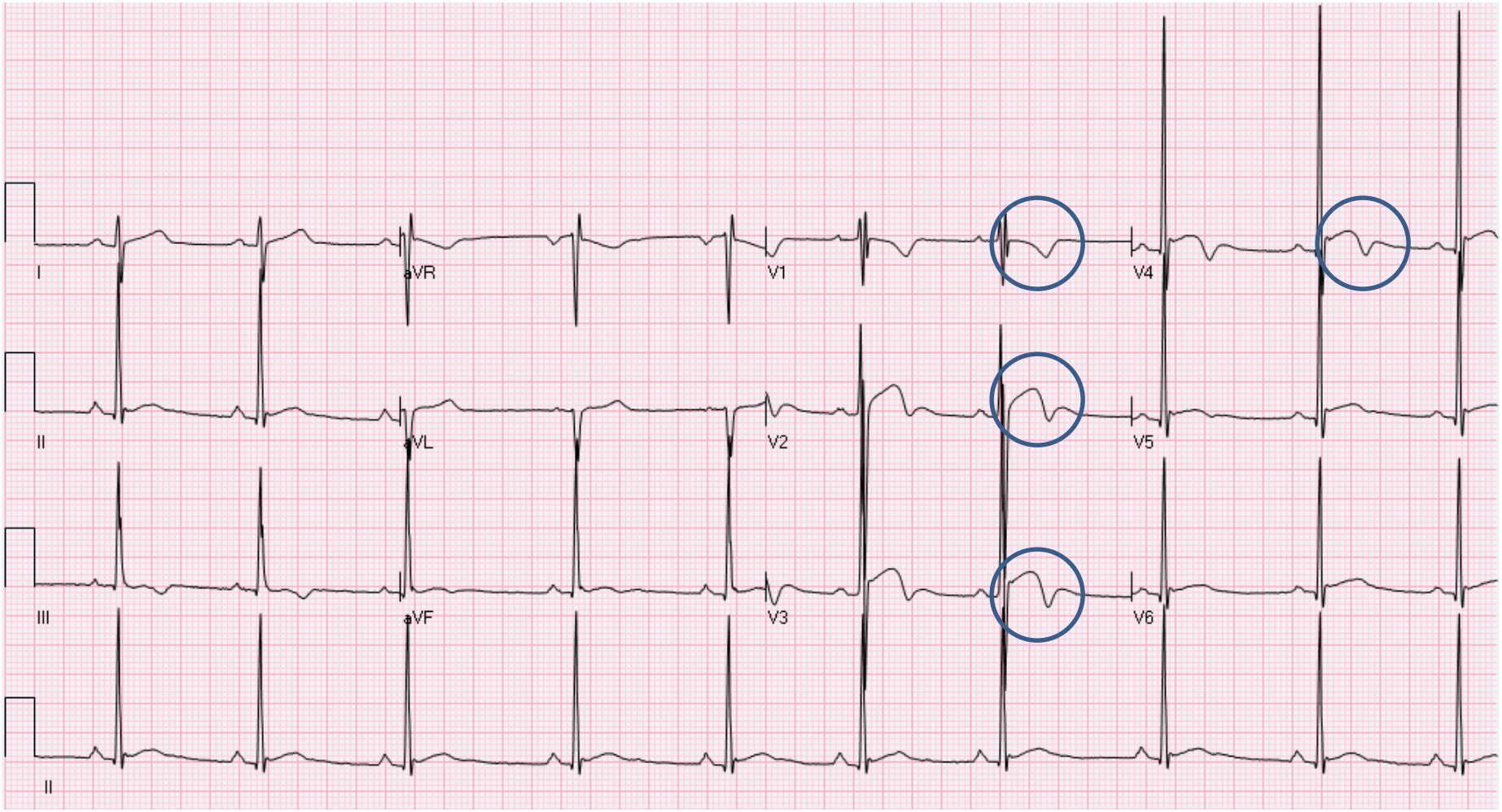
ECG from a 29 year old asymptomatic soccer player demonstrating early repolarization (J-point and ST elevation) in II, III, aVF, V4-V6 (arrows) and tall, peaked T-waves (circles). These are common, training related findings in athletes and do not require more evaluation.

Incomplete Right Bundle Branch Block

•rSR’ pattern in lead V1 •QRS duration <120 ms

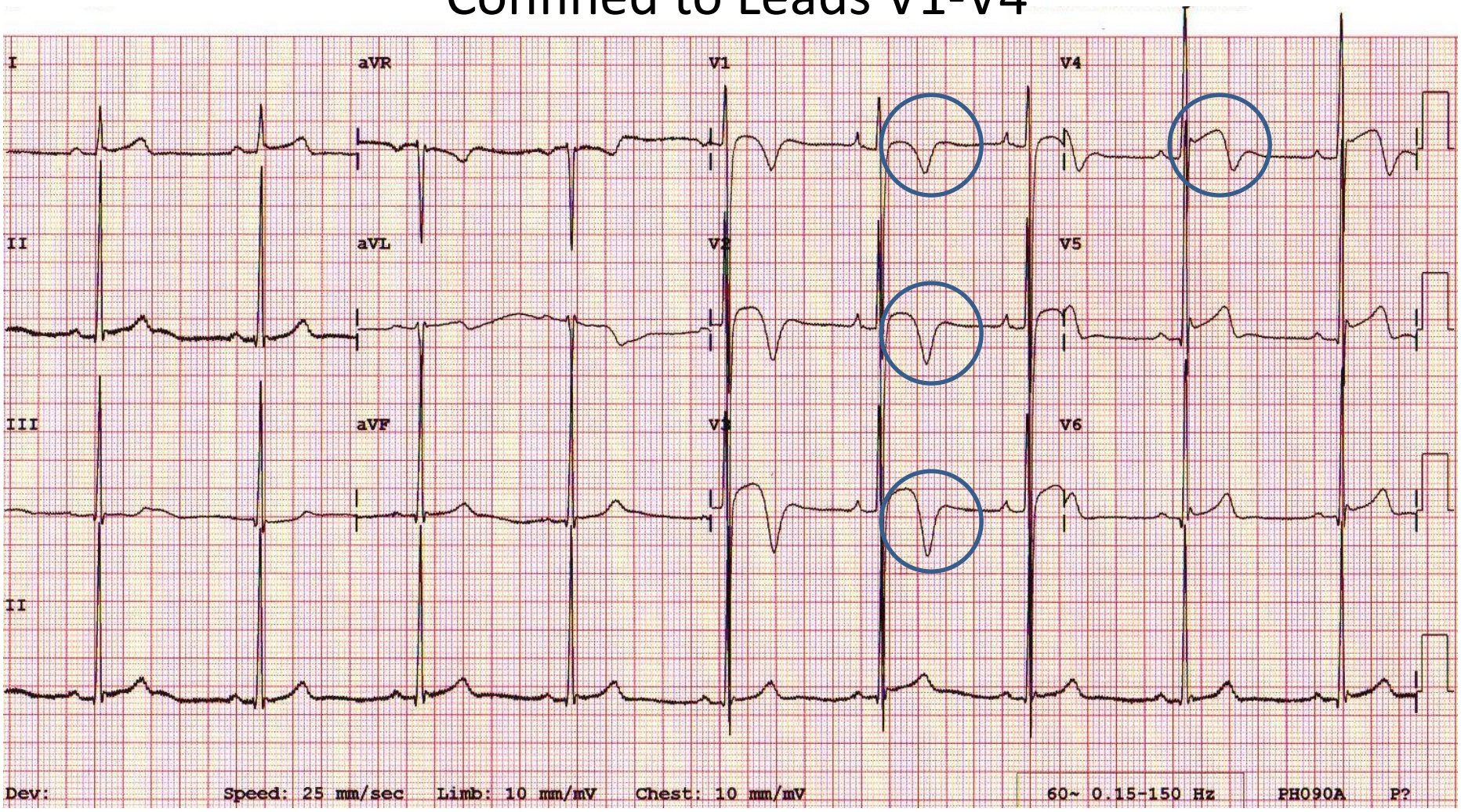


Black Athlete Repolarization Variant



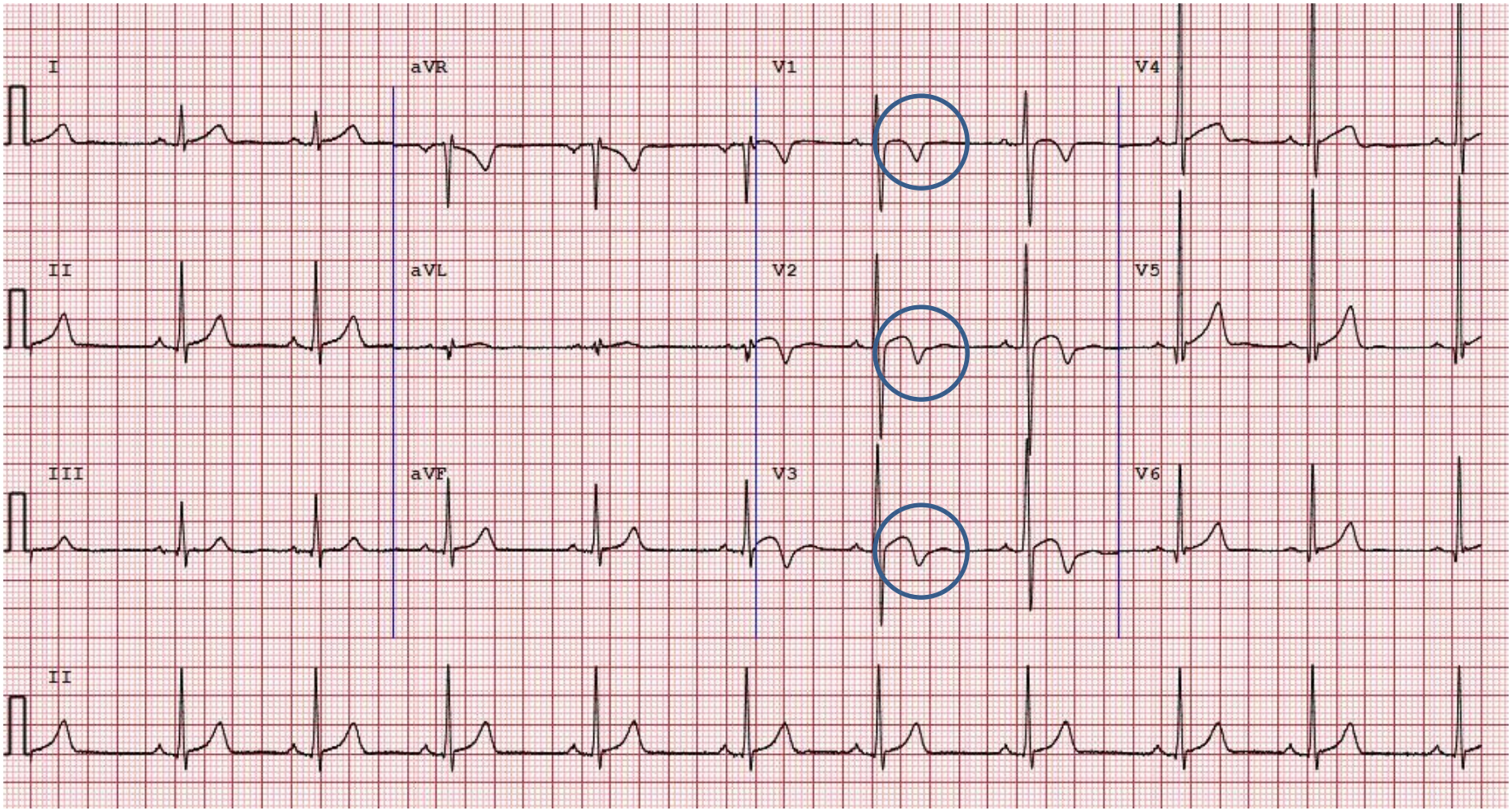
ECG from a 24 year old asymptomatic black/African soccer player demonstrating J-point elevation, convex ('domed') ST elevation followed by T wave inversion in leads V1-V4 (circles). This is a normal repolarization pattern in black/African athletes.

Black Athlete Repolarization Variant: Confined to Leads V1-V4



ECG from a black/African athlete demonstrating voltage criterion for LVH, J-point elevation and convex ('domed') ST segment elevation followed by T wave inversion in V1-V4 (circles). This is a normal repolarization pattern in black athletes.

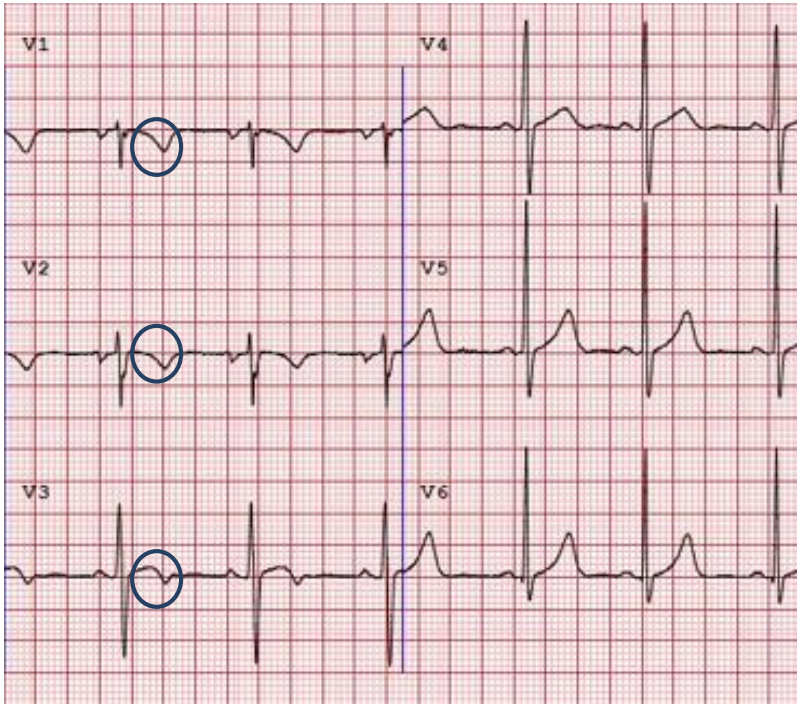
Juvenile T Wave Inversion



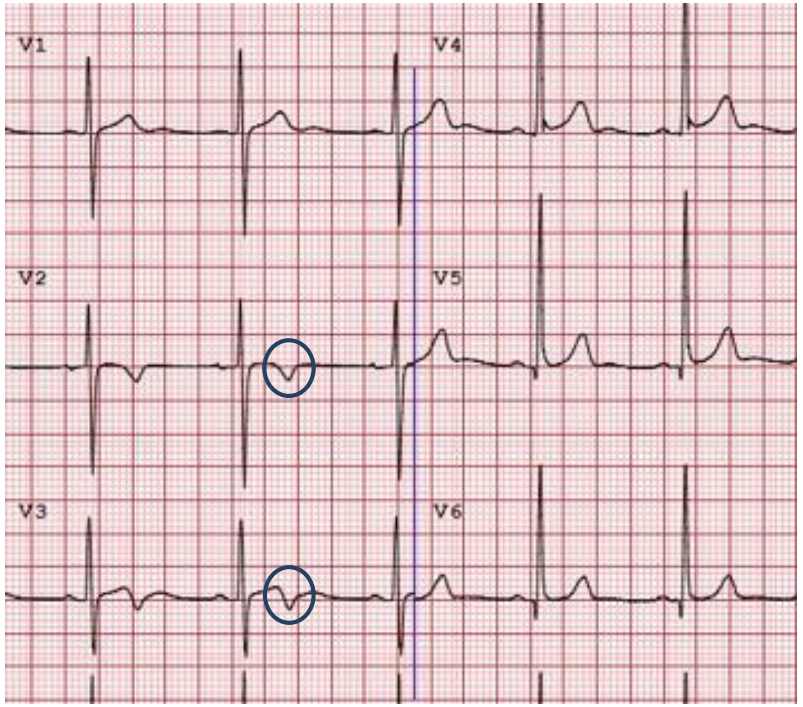
ECG from a **12 year old** asymptomatic Caucasian female soccer player demonstrating the juvenile pattern of T wave inversion in leads V1-V3 (circles). This is a normal finding in athletes < 16 years of age.

Juvenile T Wave Inversion

Age <16 yo; Independent of race; TWI in V1-V3; Does not extend to V4



13 yo Caucasian female



15 yo Asian female

No further evaluation needed

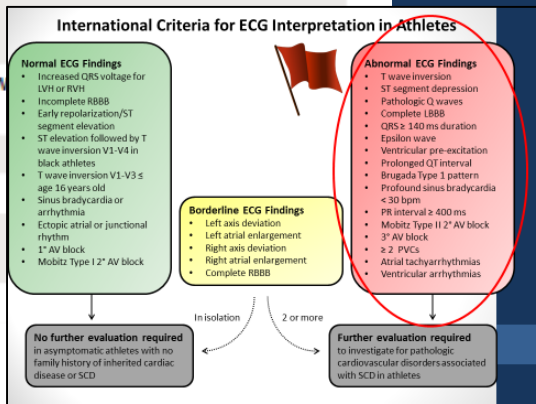
Definitions: Abnormal ECG Findings

Table 1 International consensus standards for ECG interpretation in athletes: definitions of ECG criteria

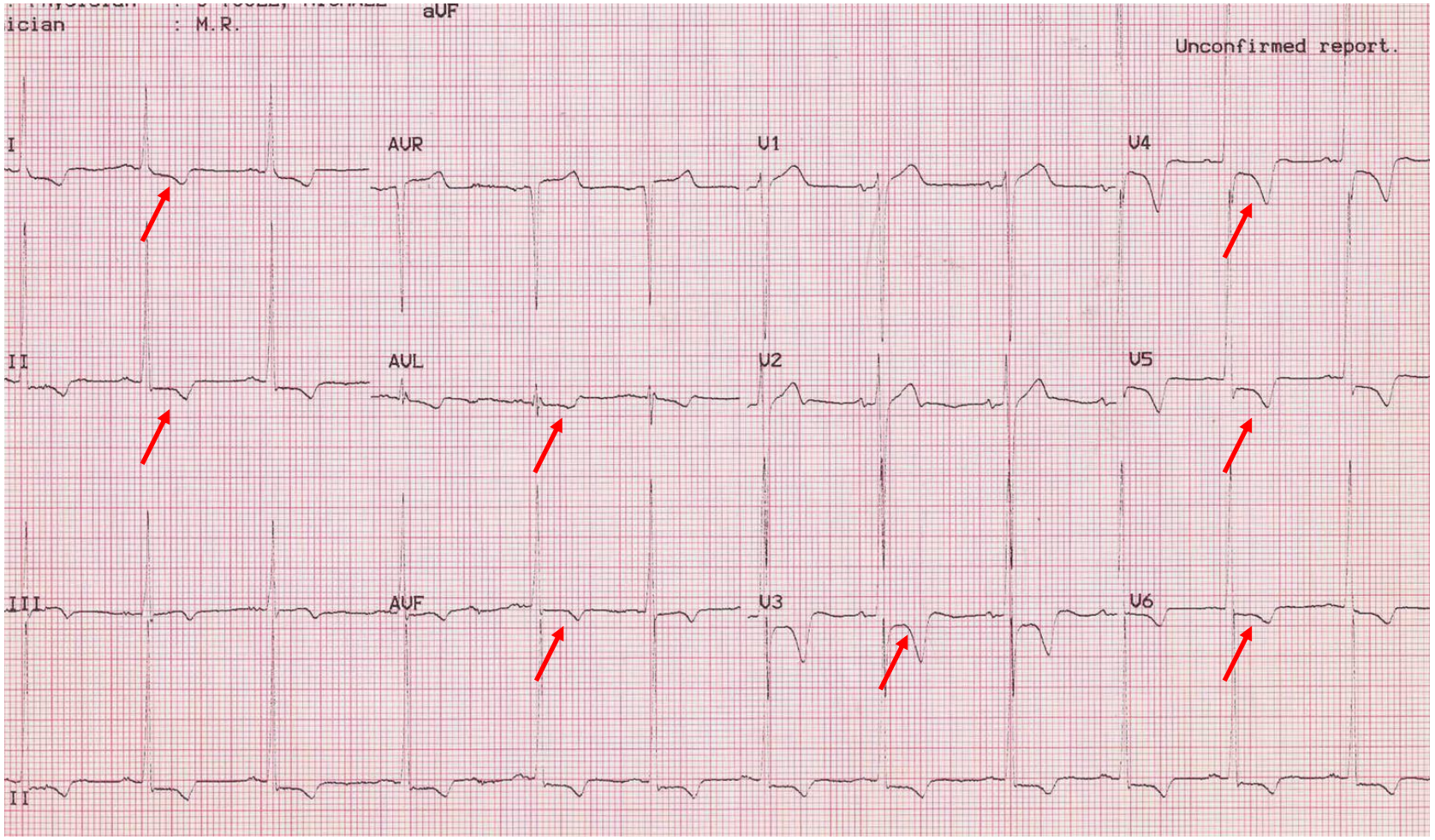
Abnormal ECG findings in athletes

These ECG findings are unrelated to regular training or expected physiological adaptation to exercise, may suggest the presence of pathological cardiovascular disease and require further diagnostic investigation.

ECG abnormality	Definition
T wave inversion	≥1 mm in depth in two or more contiguous leads; excludes leads aVR, III and V1
▶ Anterior	▶ V2-V4
	– excludes: black athletes with J-point elevation and convex ST segment elevation followed by TWI in V2-V4; athletes < age 16 with TWI in V1-V3; and biphasic T waves in only V3
▶ Lateral	▶ I and AVL, V5 and/or V6 (only one lead of TWI required in V5 or V6)
▶ Inferolateral	▶ II and aVF, V5-V6, I and AVL
▶ Inferior	▶ II and aVF
ST segment depression	≥0.5 mm in depth in two or more contiguous leads
Pathological Q waves	Q/R ratio ≥0.25 or ≥40 ms in duration in two or more leads (excluding III and aVR)
Complete left bundle branch block	QRS ≥120 ms, predominantly negative QRS complex in lead V1 (QS or rS) and upright notched or slurred R wave in leads I and V6
Profound non-specific intraventricular conduction delay	Any QRS duration ≥140 ms
Epsilon wave	Distinct low amplitude signal (small positive deflection or notch) between the end of the QRS complex and onset of the T wave in leads V1-V3
Ventricular pre-excitation	PR interval <120 ms with a delta wave (slurred upstroke in the QRS complex) and wide QRS (≥120 ms)
Prolonged QT interval*	QTc ≥470 ms (male) QTc ≥480 ms (female) QTc ≥500 ms (marked QT prolongation)
Brugada type 1 pattern	Coved pattern: initial ST elevation ≥2 mm (high take-off) with downsloping ST segment elevation follow in ≥1 leads in V1-V3
Profound sinus bradycardia	<30 beats per minute or sinus pauses ≥3 s
Profound 1° atrioventricular block	≥400 ms
Mobitz type II 2° atrioventricular block	Intermittently non-conducted P waves with a fixed PR interval
3° atrioventricular block	Complete heart block

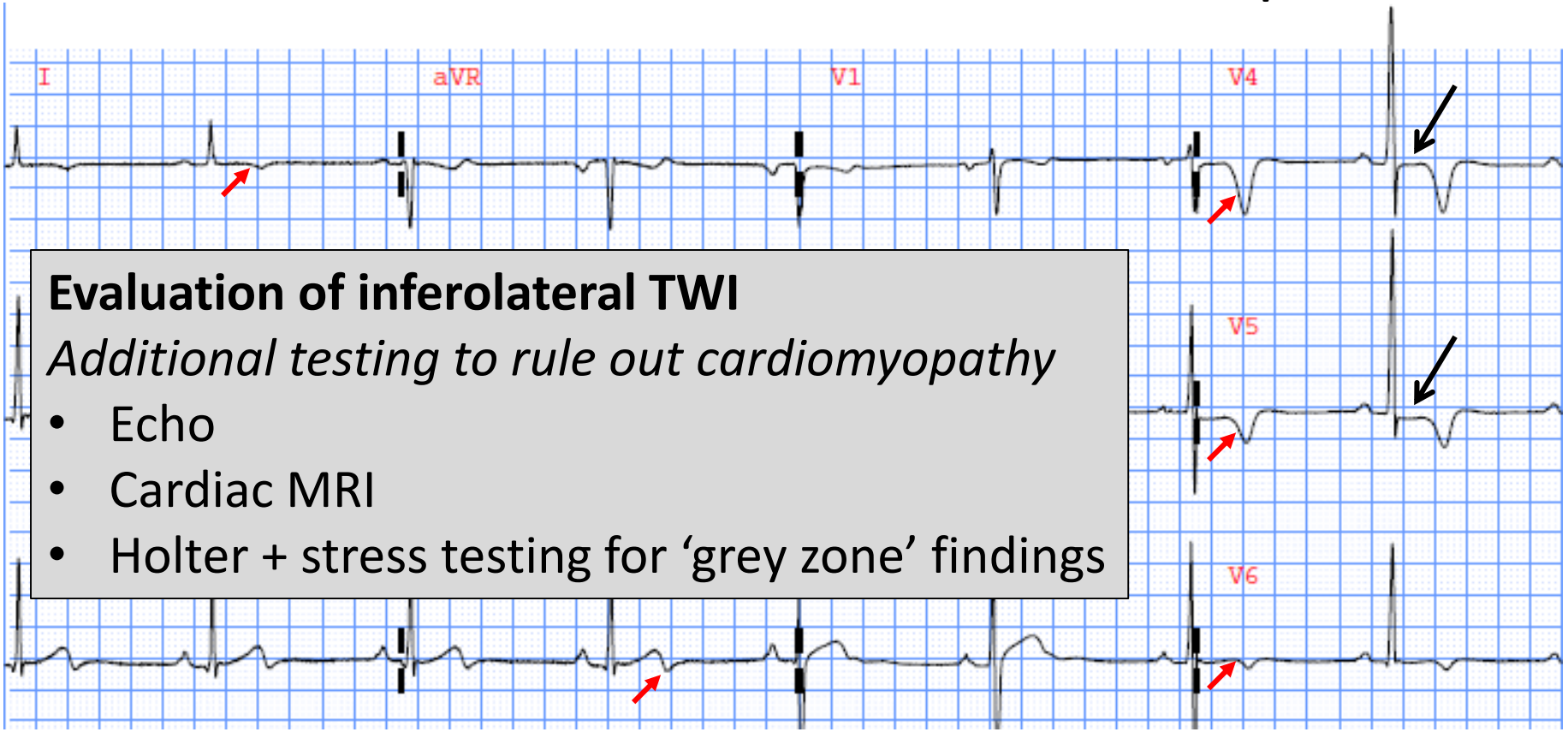


Inferolateral T Wave Inversion and ST Depression



Abnormal ECG in a patient with hypertrophic cardiomyopathy. Note T wave inversion and ST segment depression in the inferolateral leads (arrows).

Inferolateral T Wave Inversion and ST Depression



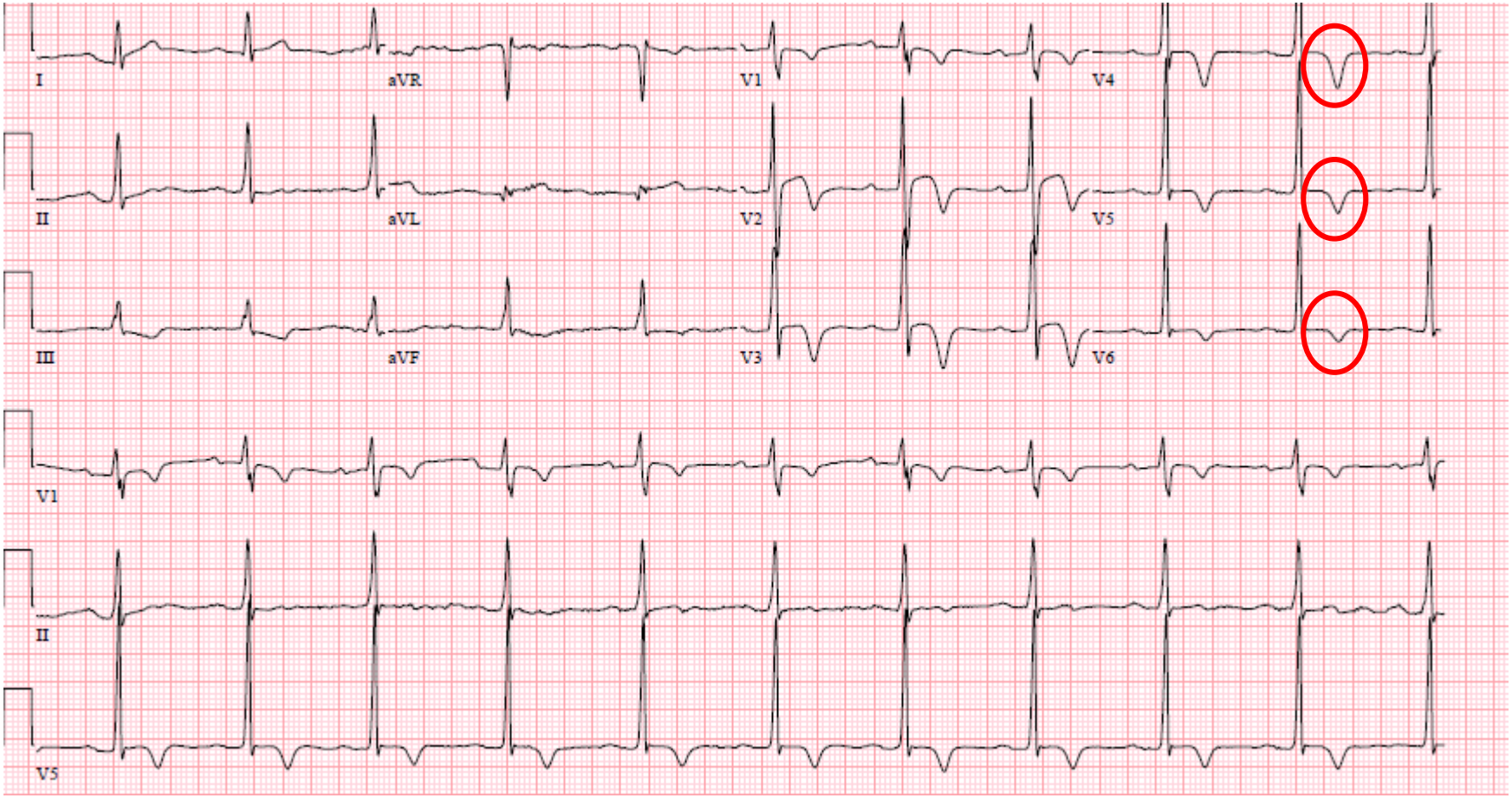
Evaluation of inferolateral TWI

Additional testing to rule out cardiomyopathy

- Echo
- Cardiac MRI
- Holter + stress testing for 'grey zone' findings

Abnormal ECG from a patient with hypertrophic cardiomyopathy. Note T wave inversions in I, aVL, V4-V6, II and aVF (red arrows), as well as ST segment depression in V4-V5 (black arrows).

Lateral T Wave Inversion



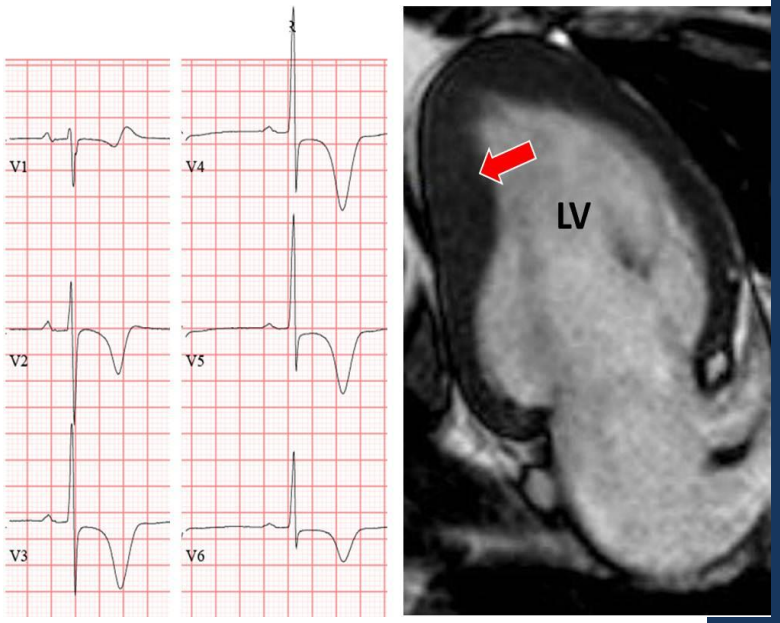
Markedly abnormal ECG showing TWI ≥2 mm in V4-V6. Note that the ST segment preceding TWI in V4-6 is flat or downsloping.

Table 2 Evaluation of ECG abnormalities in athletes

ECG abnormality	Potential cardiac disease*	Recommended evaluation†	Considerations
T wave inversion in the lateral or inferolateral leads	HCM DCM LVNC ARVC (with predominant left ventricular involvement) Myocarditis	Echocardiogram Cardiac MRI Exercise ECG test Minimum 24 hours ECG monitor	Lateral or inferolateral T wave inversion is common in primary myocardial disease. Cardiac MRI should be a routine diagnostic test for this ECG phenotype and is superior to echocardiography for detecting apical HCM, left ventricular hypertrophy localised to the free lateral wall, ARVC with predominant left ventricular involvement and myocarditis. If cardiac MRI is not available, echocardiography with contrast should be considered as an alternative investigation for apical HCM in patients with deep T wave inversion in leads V5-V6. Consider family evaluation if available and genetic screening. Annual follow-up testing is recommended throughout athletic career in athletes with normal results.
T wave inversion isolated to the inferior leads	HCM DCM LVNC Myocarditis	Echocardiogram	Consider cardiac MRI based on echocardiogram findings or clinical suspicion.
T wave inversion in the anterior leads‡	ARVC DCM	Echocardiogram Cardiac MRI Exercise ECG test Minimum 24 hours ECG monitor Signal averaged ECG	The extent of investigations may vary based on clinical suspicion for ARVC and results from initial testing.
ST segment depression	HCM DCM LVNC ARVC Myocarditis	Echocardiogram	Consider cardiac MRI and additional testing based on echocardiogram findings or clinical suspicion.
Pathological Q waves	HCM DCM LVNC Myocarditis Prior myocardial infarction	Echocardiogram Coronary artery disease risk factor assessment Repeat ECG for septal (V1-V2) QS pattern; above investigations recommended if septal Q waves are persistent	Consider cardiac MRI (with perfusion study if available) based on echocardiogram findings or clinical suspicion. In the absence of cardiac MRI, consider exercise stress testing, dobutamine stress echocardiogram or a myocardial perfusion scan for evaluation of coronary artery disease in athletes with suspicion of prior myocardial infarction or multiple risk factors for coronary artery disease.
Complete left bundle branch block	DCM HCM LVNC Sarcoidosis Myocarditis	Echocardiogram Cardiac MRI (with stress perfusion study)§	A comprehensive cardiac evaluation to rule out myocardial disease should be considered.

Evaluation of Lateral or Inferolateral TWI

- Comprehensive evaluation to r/o cardiomyopathy
- Echocardiogram
- **Cardiac MRI should be a routine diagnostic test for this ECG phenotype**
  - Apical HCM, DCM, LVNC, AC with LV involvement, non-ischemic LV scar
- 24 hour ECG monitor + stress testing for ‘grey zone’ findings

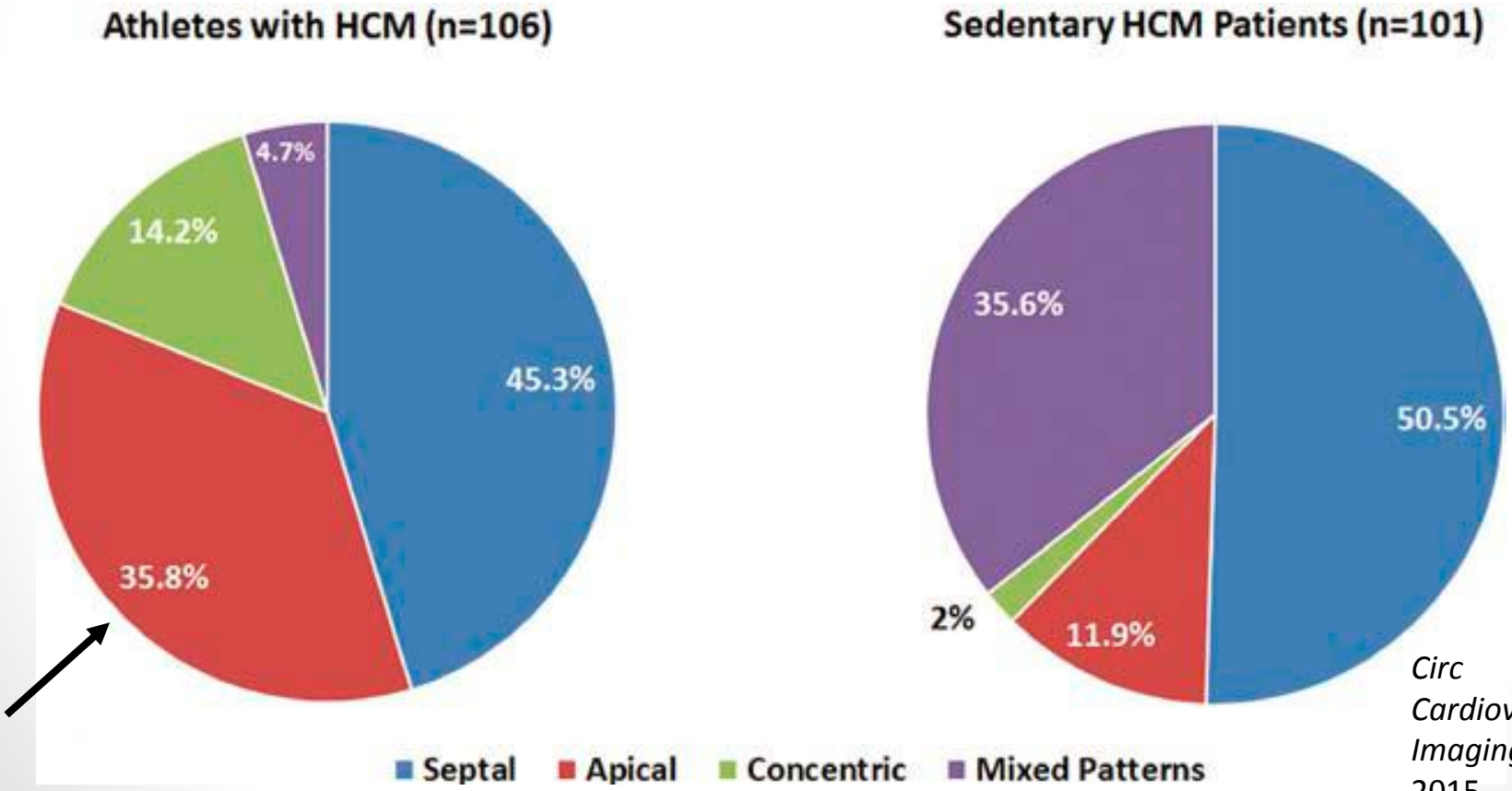


Apical HCM

Clinical Profile of Athletes With Hypertrophic Cardiomyopathy

Nabeel Sheikh, MRCP; Michael Papadakis, MD; Frédéric Schnell, PhD; Vasileios Panoulas, MD, PhD; Aneil Malhotra, MRCP; Mathew Wilson, PhD; François Carré, PhD; Sanjay Sharma, MD

Differences in LVH patterns between athletes with HCM and sedentary HCM patients.



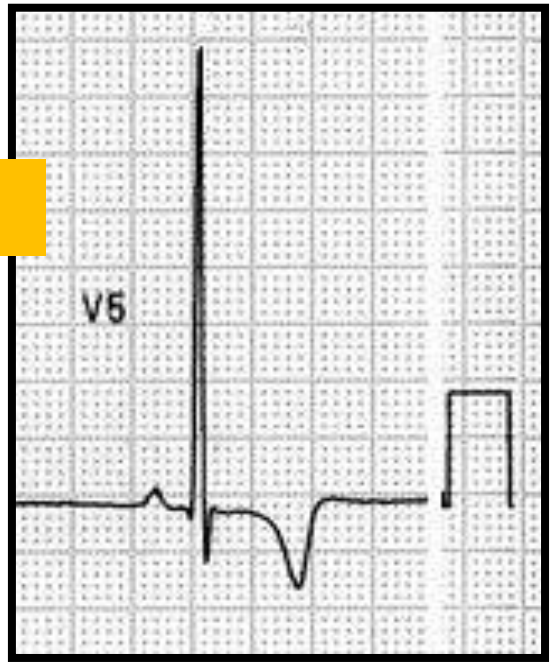
Circ Cardiovasc Imaging 2015

Long-term Follow-up of Athletes with Markedly Abnormal ECGs

Pelliccia; *NEJM* 2008

Study Group;
Normal Cardiac Imaging

81



9-year Follow-up

No Symptoms;
No CV disease

70

6%

6

Other CV Disease

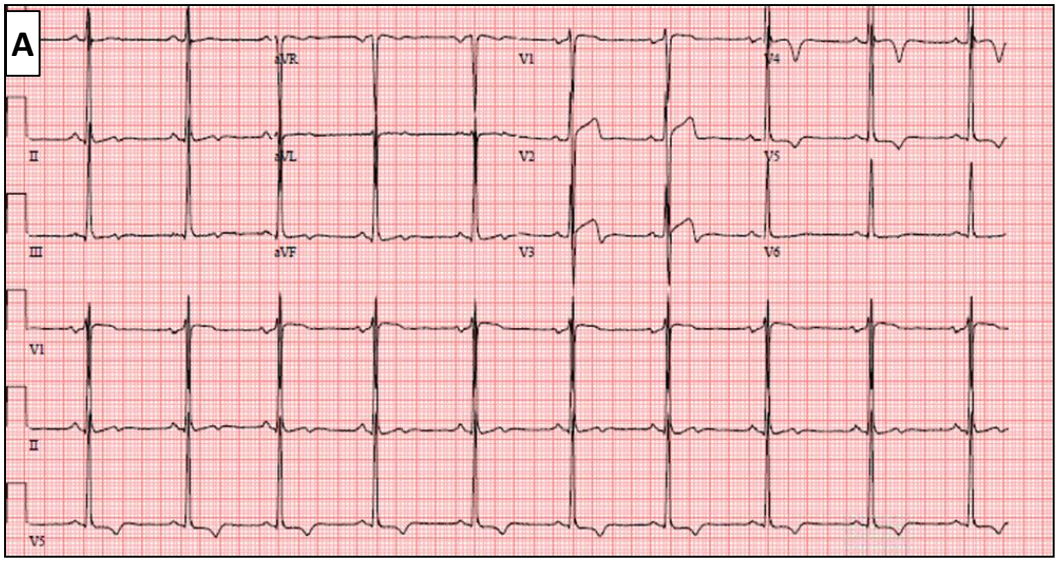
5

1 Sudden Death,
1 Cardiac Arrest

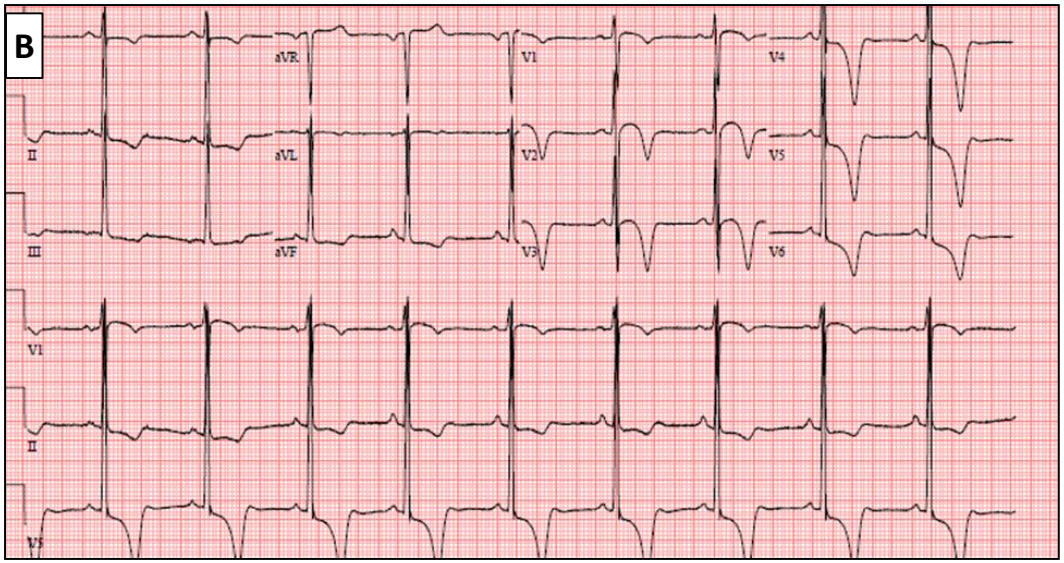
Cardiomyopathies
(HCM 3; ARVC 1; DCM 1)

Serial Follow-up

19 yo African-American male, college basketball player



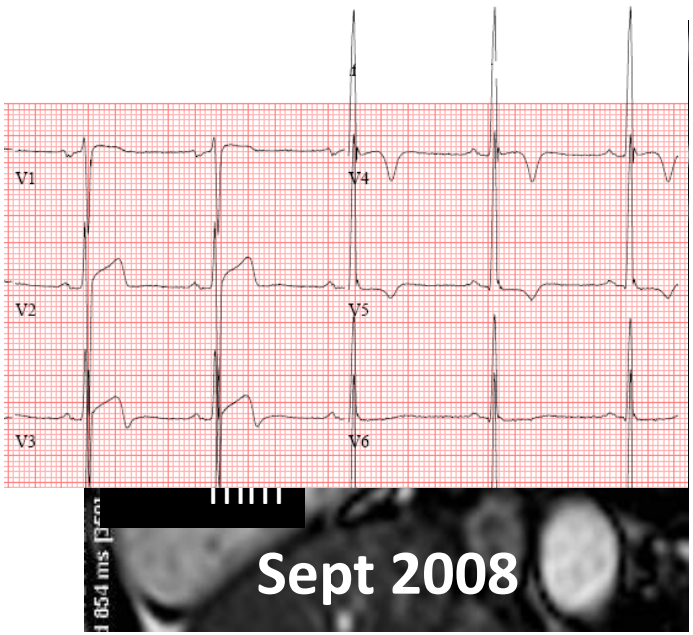
September 2008
Echo and CMR
non-diagnostic

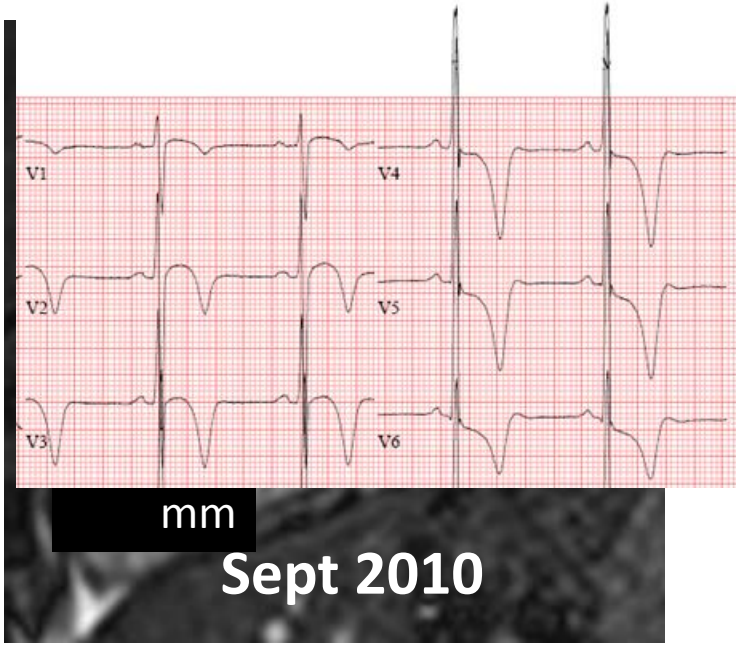


September 2010
CMR apical
hypertrophy 20 mm
with +LGE

Cardiac MRI Comparison

Midventricular Short Axis Views

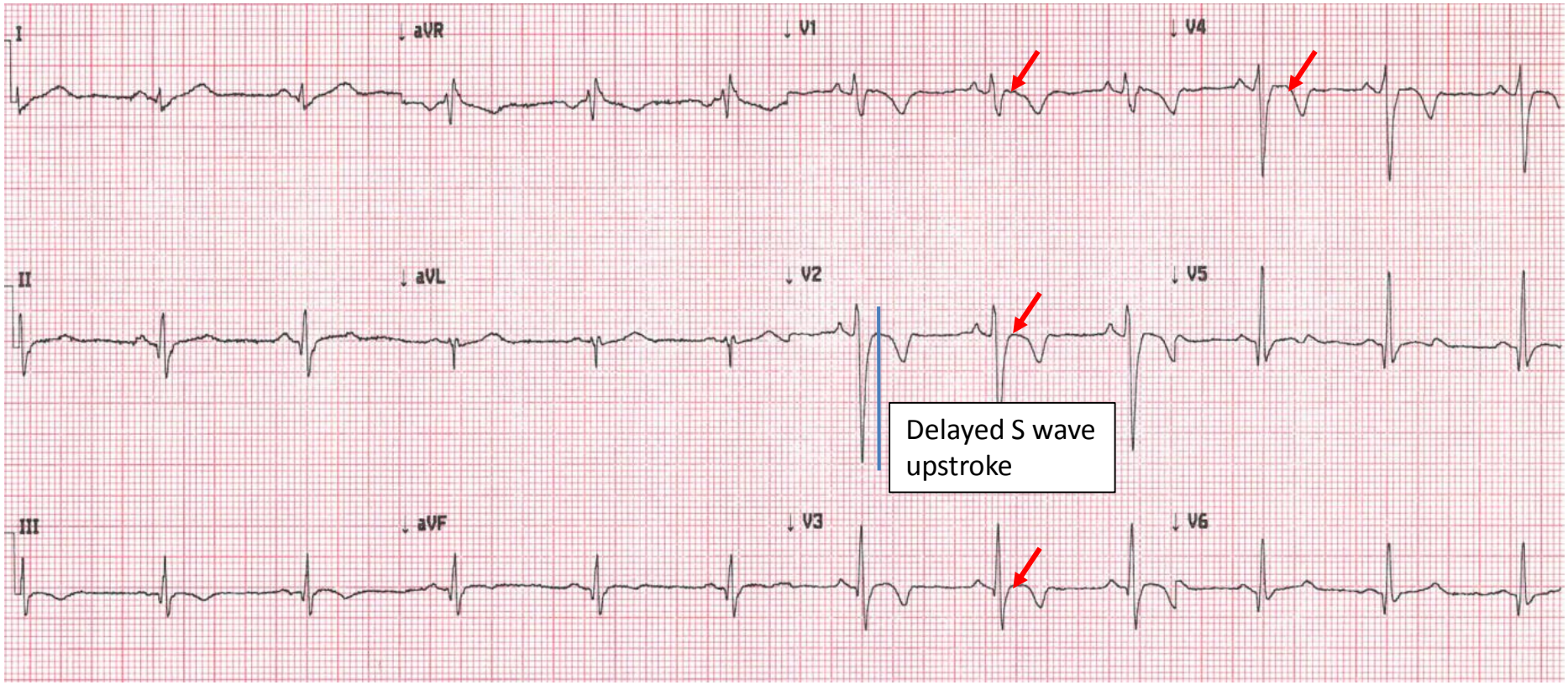




Hypertrophy of interventricular septum over 2 years

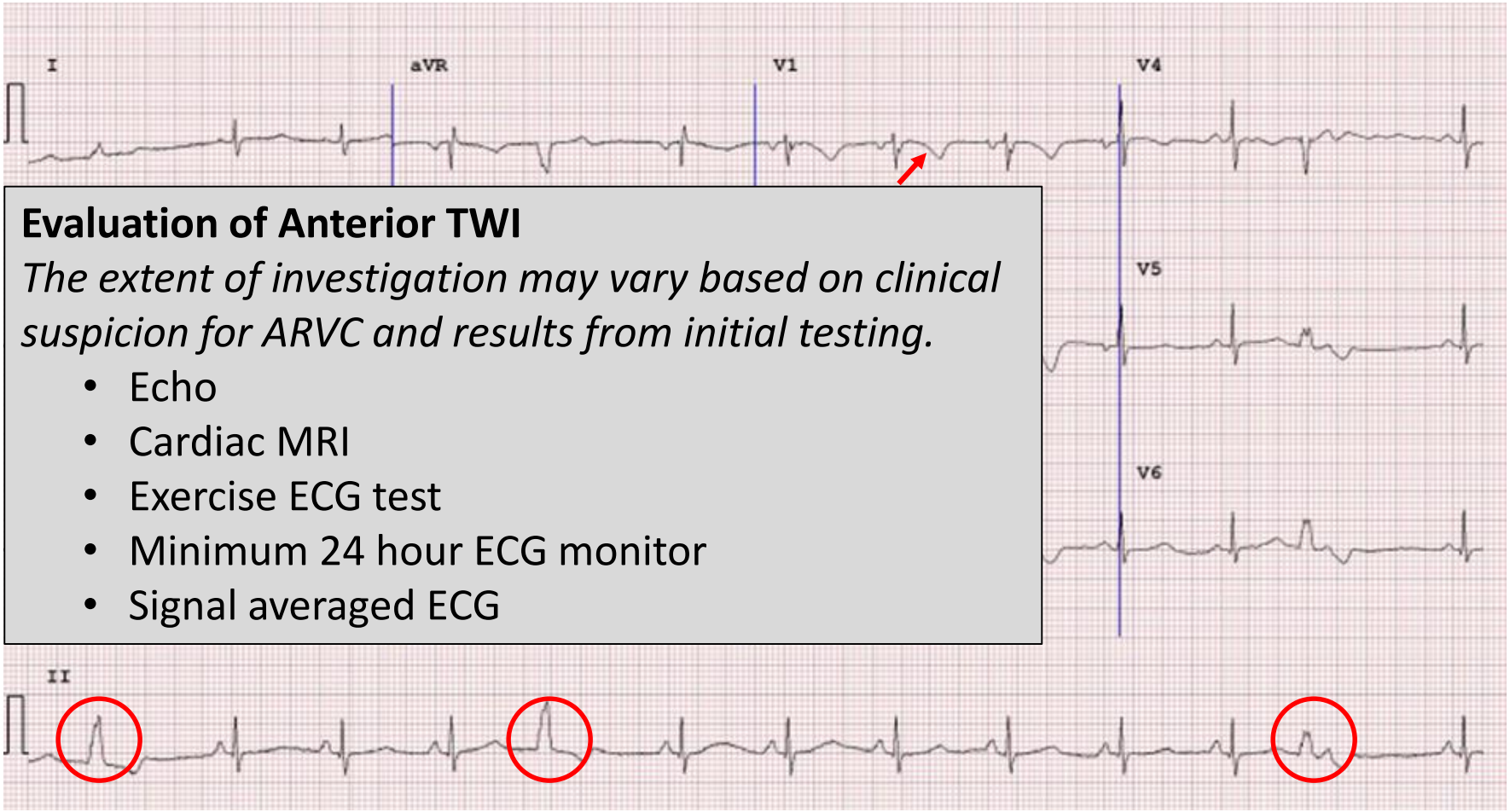
Yearly repeat of ECG and cardiac imaging indicated for athletes with pathological lateral or inferolateral TWI and initial normal imaging studies.

Anterior T Wave Inversion



21 yo Caucasian male with ECG demonstrating anterior T wave inversion (V1-V4) preceded by a **non-elevated J-point and ST segment**. Delayed S wave upstroke (≥ 55 ms) in V2 and low voltage (<5 mm) QRS complexes in limb leads I and aVL suggest possible ARVC.

Anterior T Wave Inversion



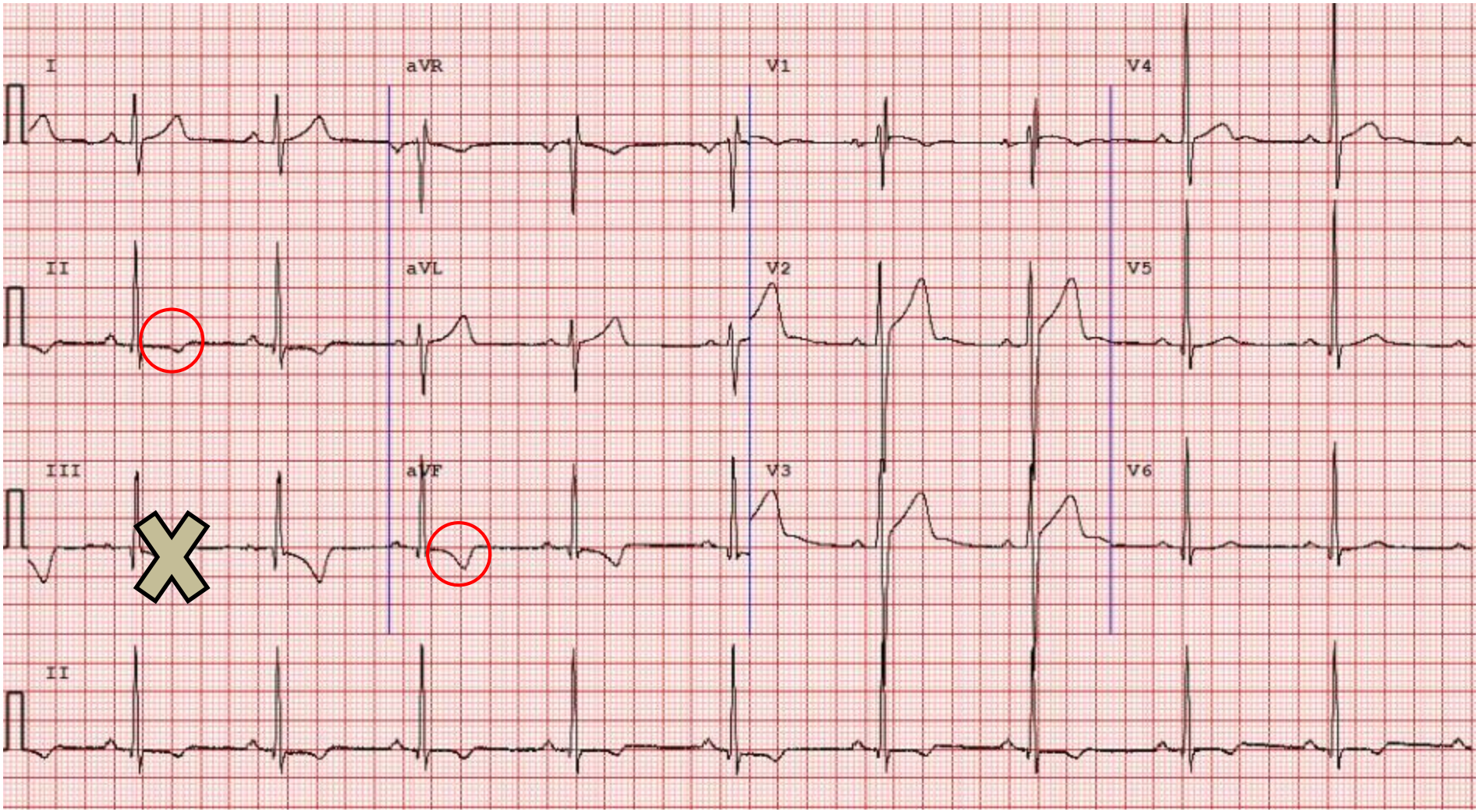
Evaluation of Anterior TWI

The extent of investigation may vary based on clinical suspicion for ARVC and results from initial testing.

- Echo
- Cardiac MRI
- Exercise ECG test
- Minimum 24 hour ECG monitor
- Signal averaged ECG

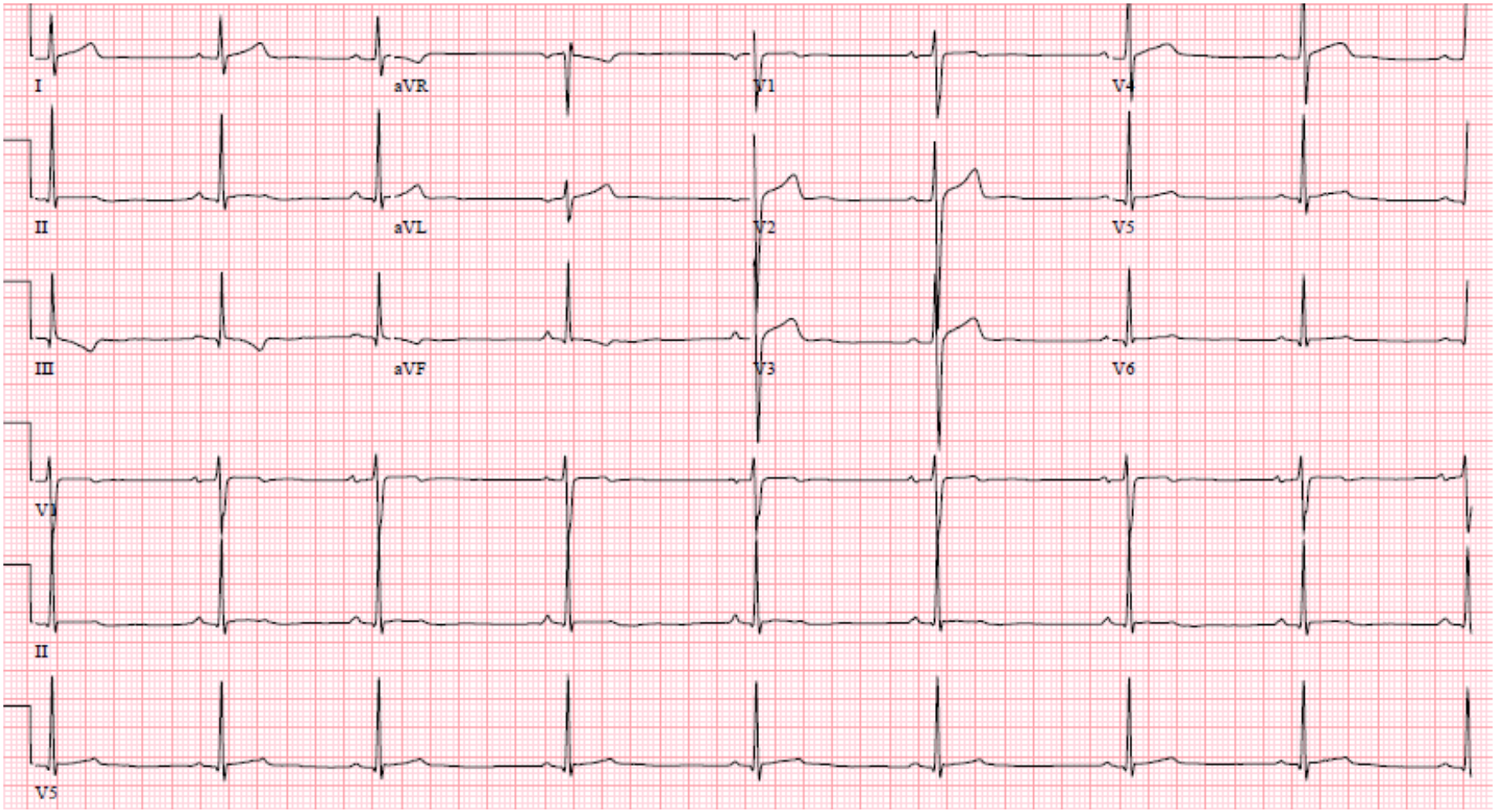
ECG from a patient with ARVC. Note pathological TWI in V1-V3 (arrows) preceded by a flat or downsloping ST segment and without J-point elevation. PVCs also present (circles).

Inferior T Wave Inversion

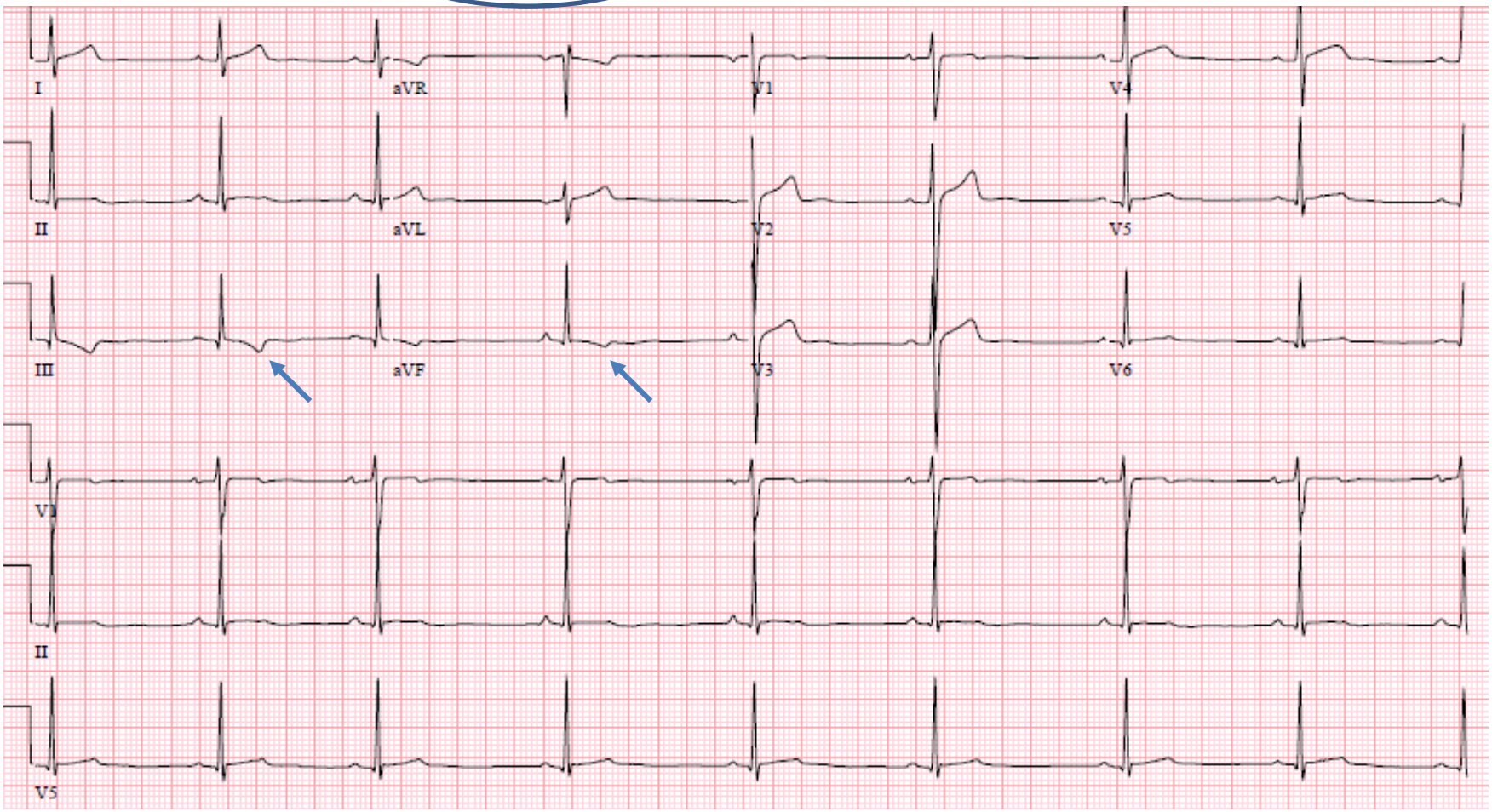


ECG demonstrates TWI in the inferior leads II and aVF. This is an abnormal ECG and requires further evaluation (echocardiogram).

Normal or Abnormal?



Normal or Abnormal?

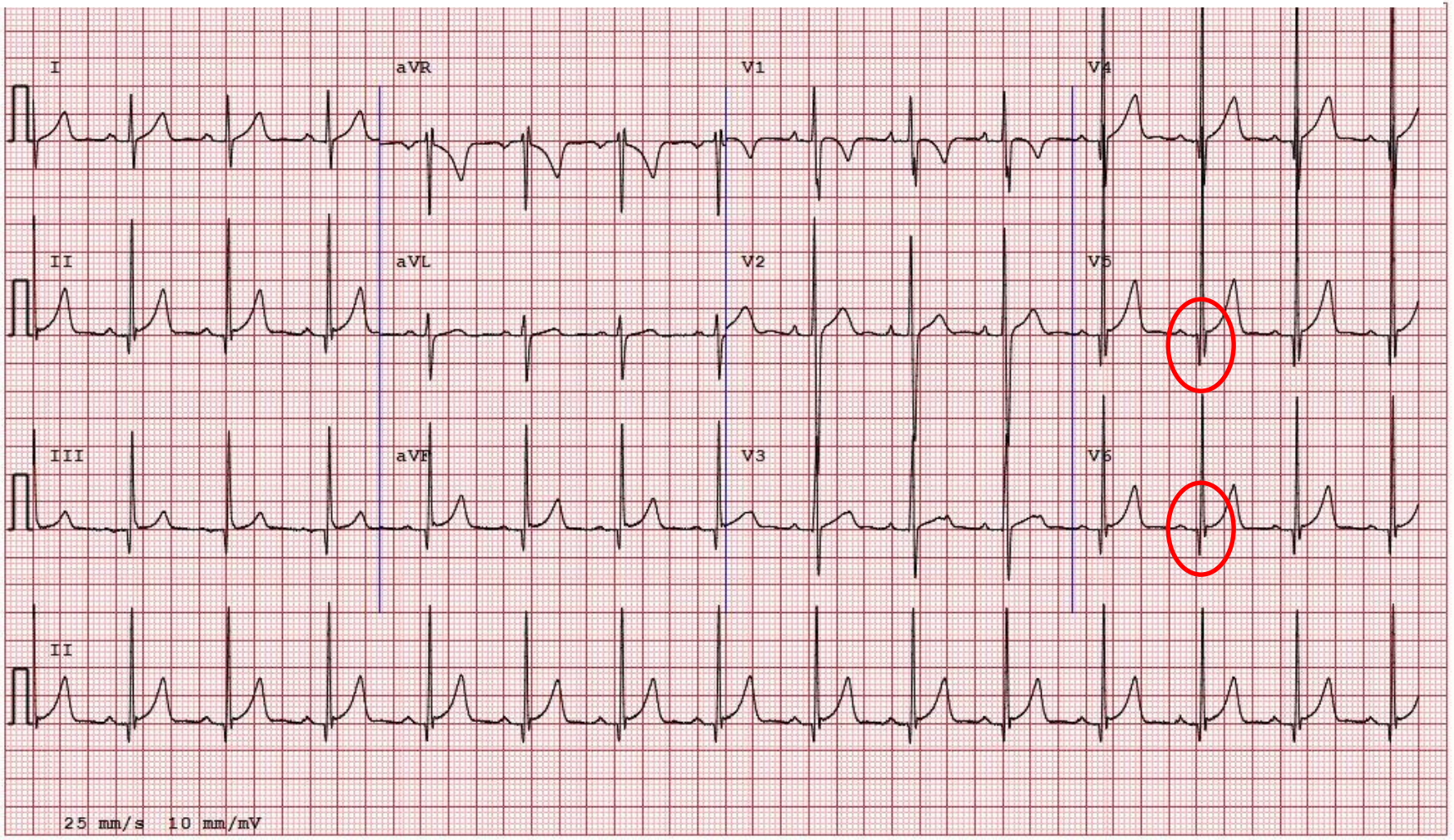


Cardiology over-read: “Nonspecific T wave abnormality” and “Abnormal ECG”

<u>Note</u>: This is a normal ECG. “Nonspecific T wave abnormality” is not part of the criteria. TWI in lead III is excluded. T wave flattening (II, V6) is also not part of the criteria. No further evaluation needed.

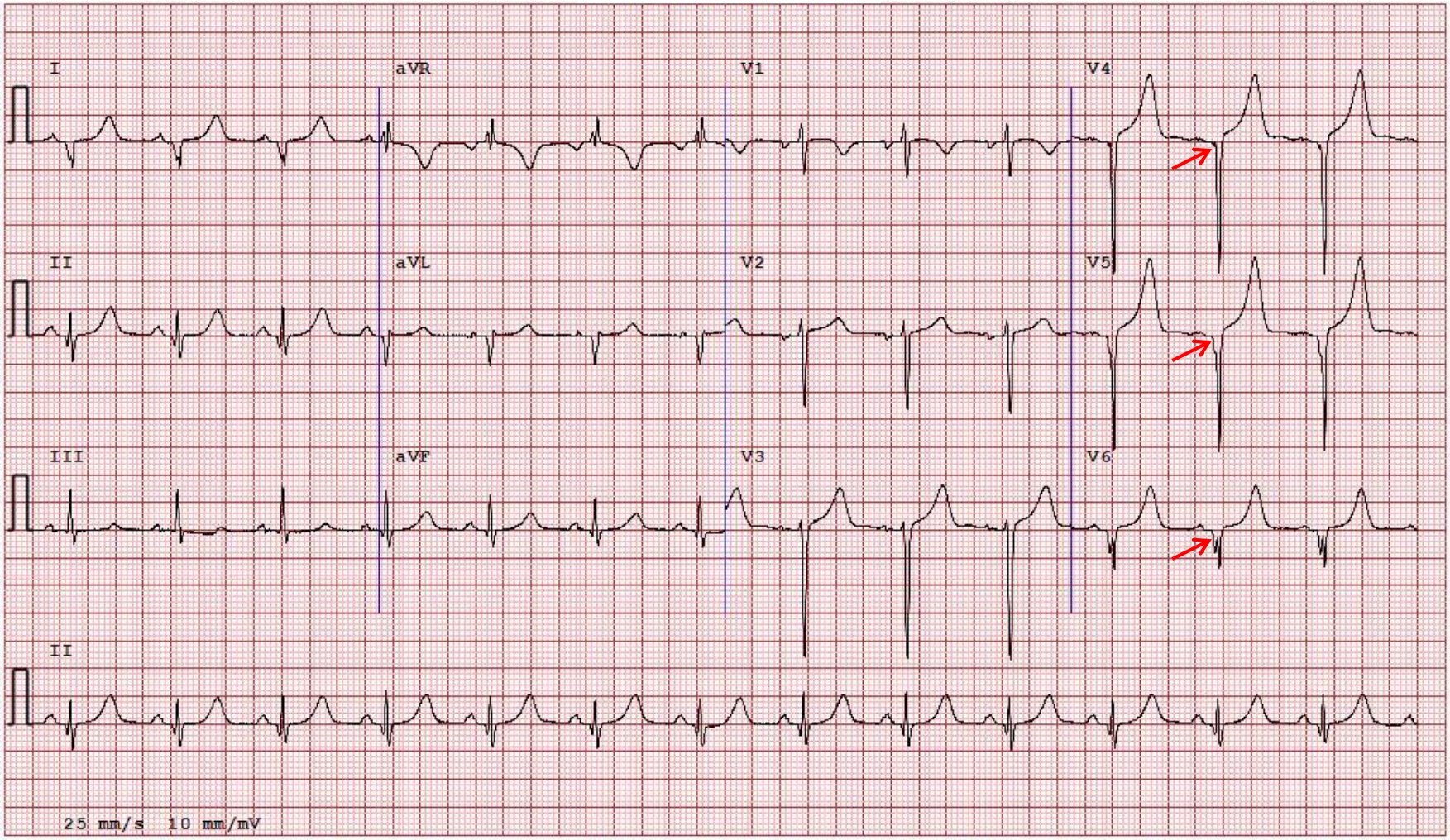
Pathologic Q Waves: Old Criteria

> 3 mm depth is out!



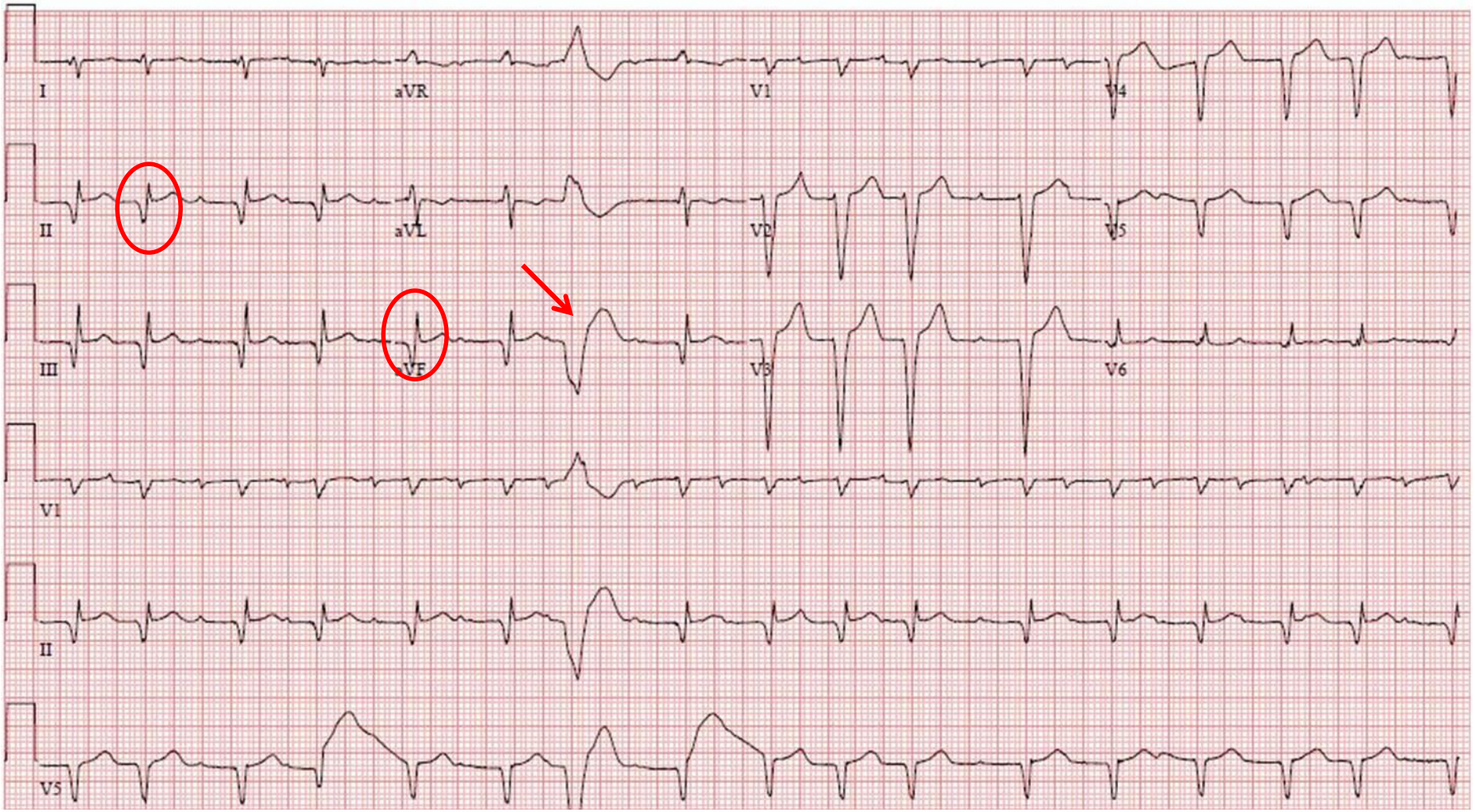
Pathologic Q Waves

New Criteria: Q/R ratio ≥ 0.25 or Q wave ≥ 40 ms in duration



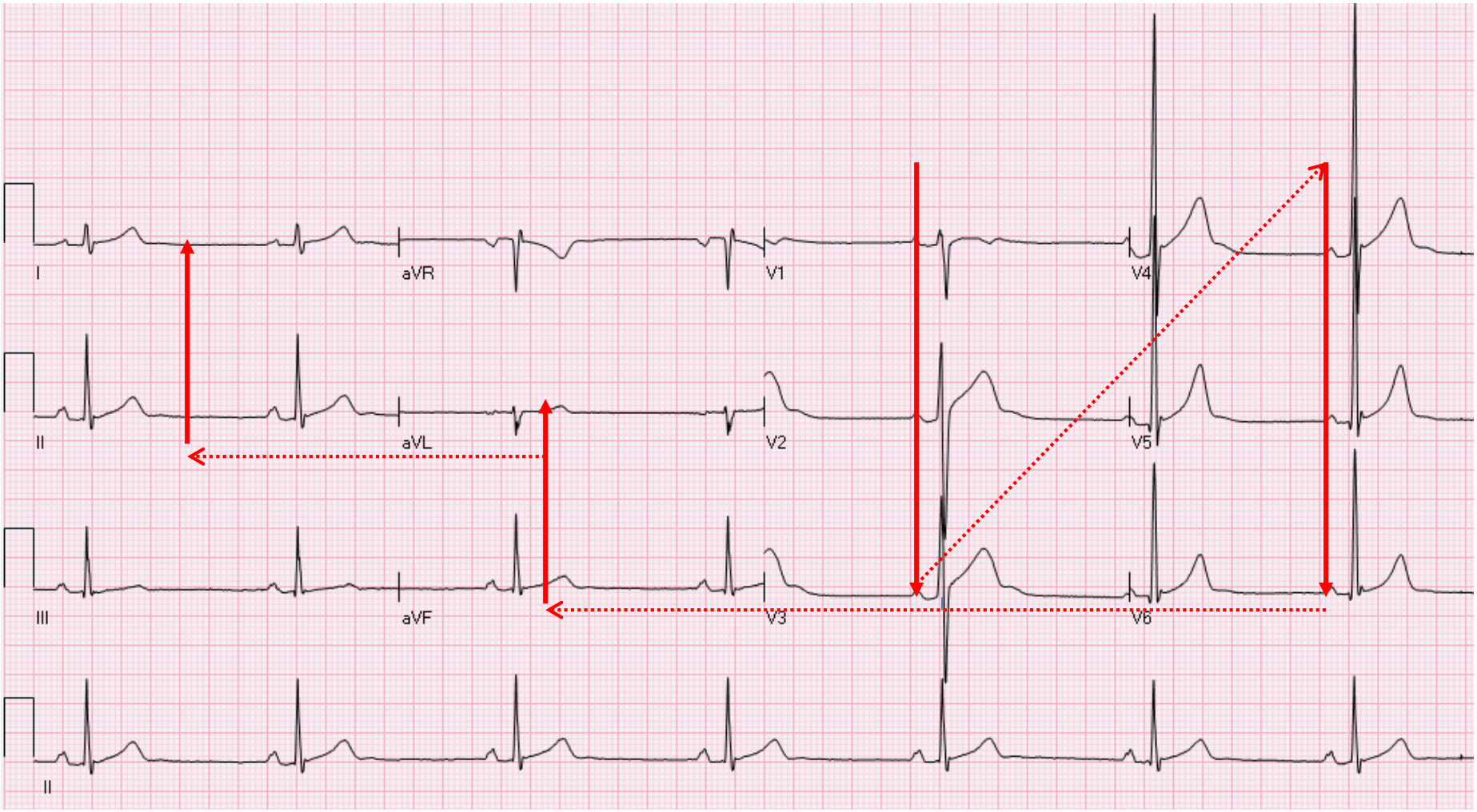
Pathologic Q Waves

Q/R ratio ≥ 0.25 or Q wave ≥ 40 ms in duration



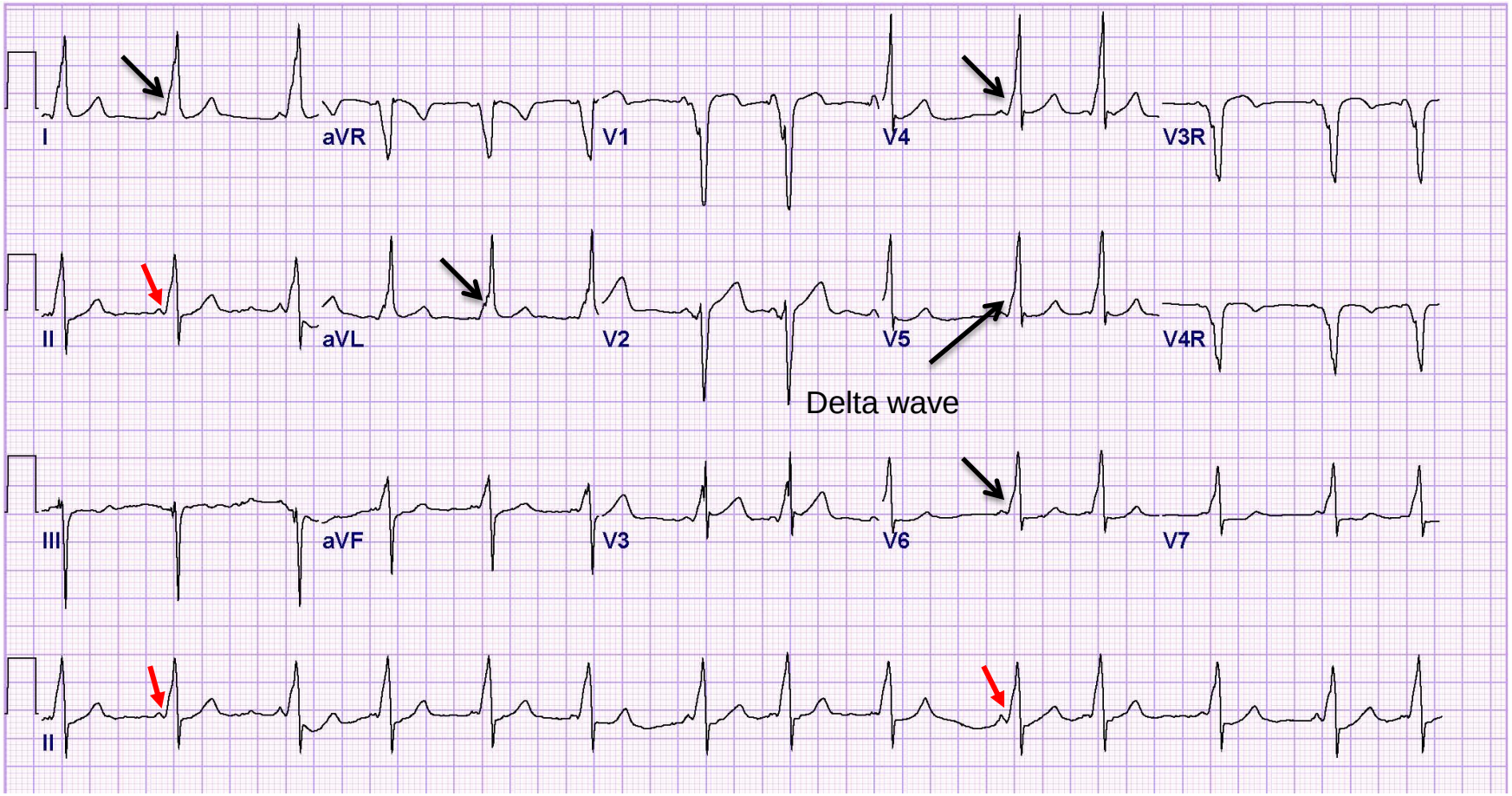
ECG of a young patient with dilated cardiomyopathy. Note inferior Q waves (II and aVF), poor R wave progression across the precordial leads with deep S waves in V1-V3, and a single premature ventricular complex (arrow). High degree AV block is also present.

Step-2: ECG Interpretation in Athletes



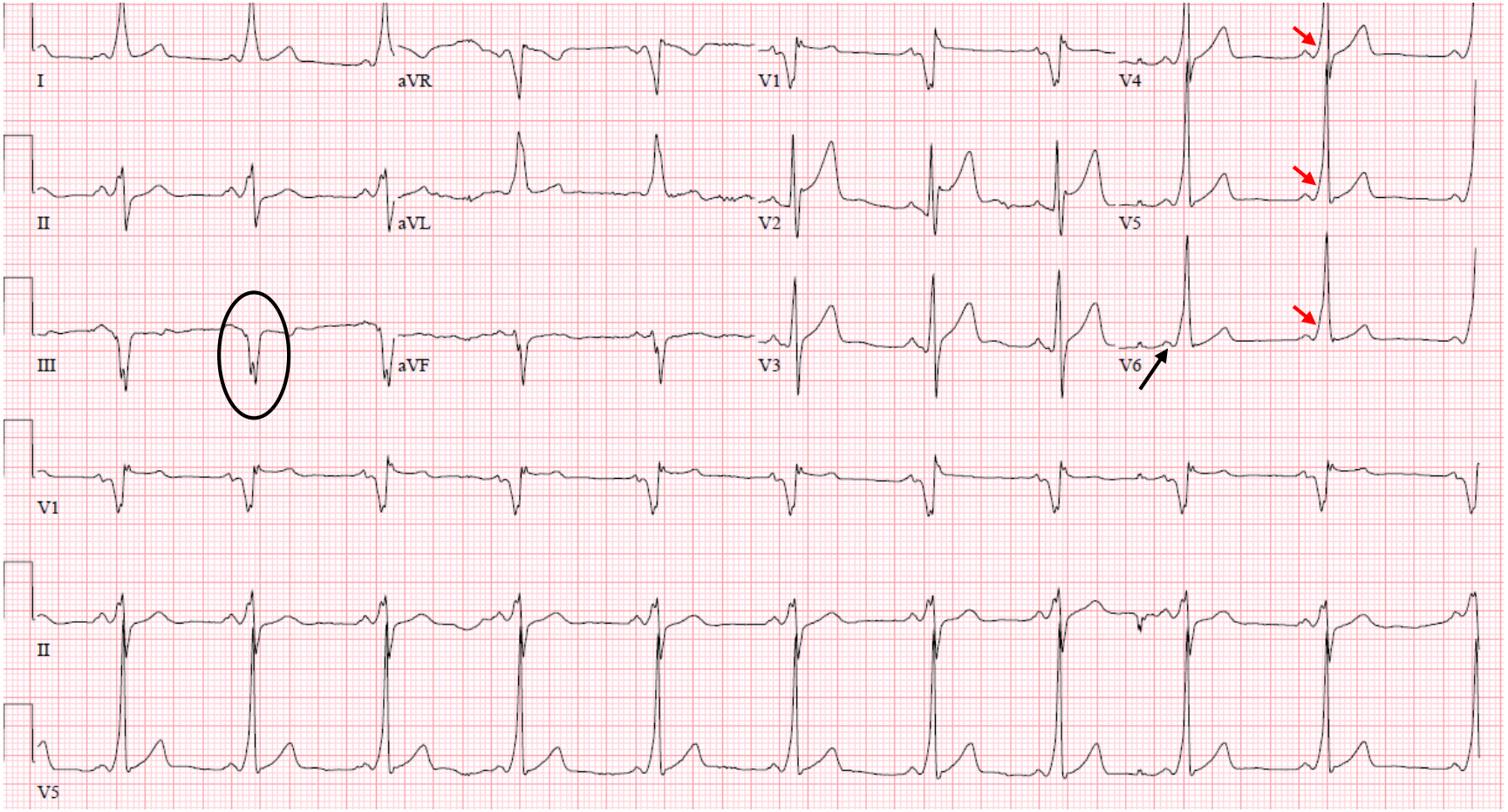
Where to look?	What to look for?
2. Precordial (V1-V6) then limb leads (aVF, aVL, II, I)	QRS morphology: pre-excitation, BBB, conduction delay, Brugada type 1

Pre-excitation / WPW



ECG demonstrating the classic findings of Wolff-Parkinson-White pattern with a short PR interval (< 120 ms), delta wave (slurred QRS upstroke), and prolonged QRS (> 120 ms).

Ventricular Pre-excitation / Wolff Parkinson White



WPW classic findings:

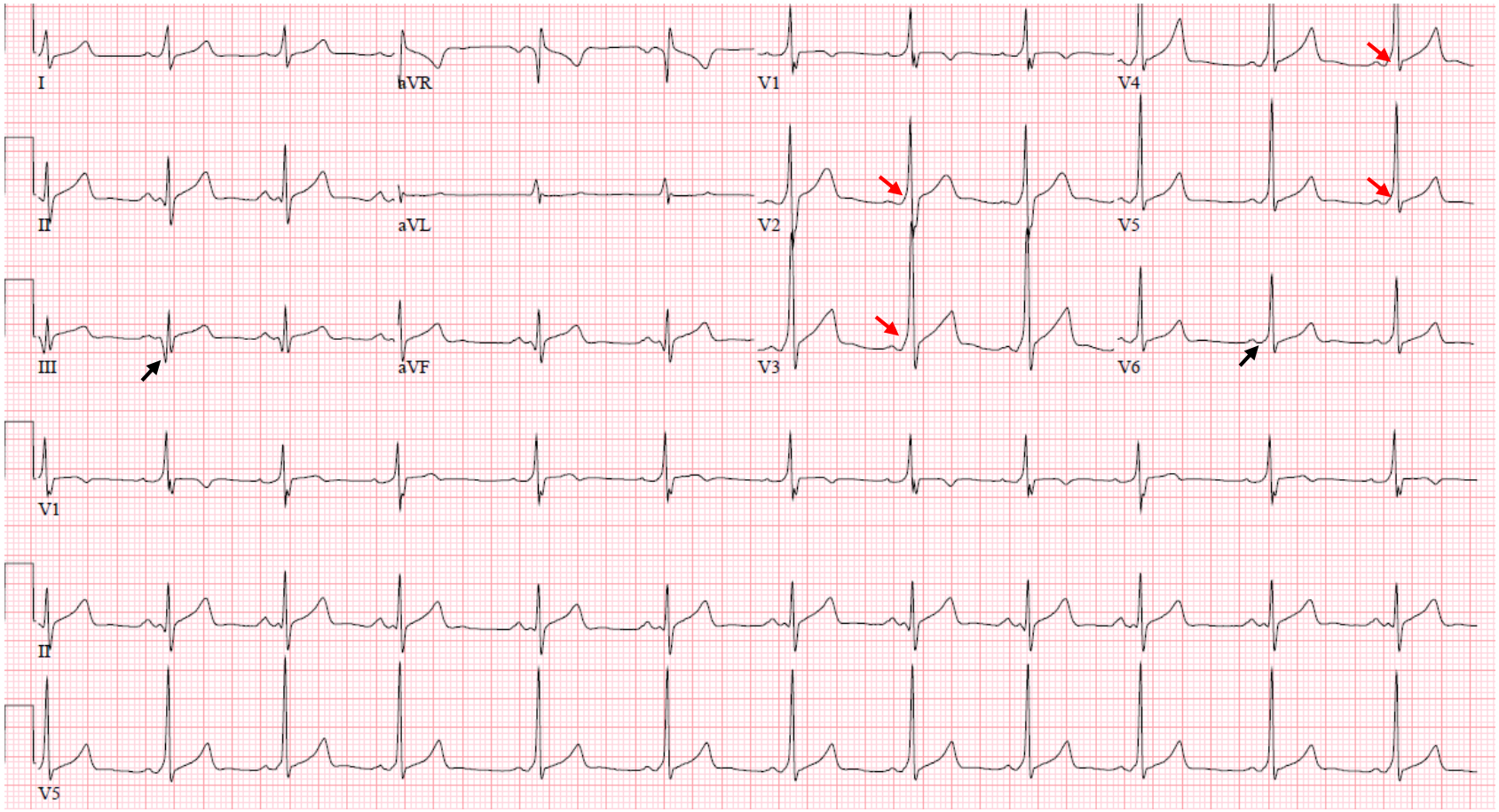
- Short PR <120 ms
- Delta wave
- Wide QRS >120 ms

WPW additional findings:

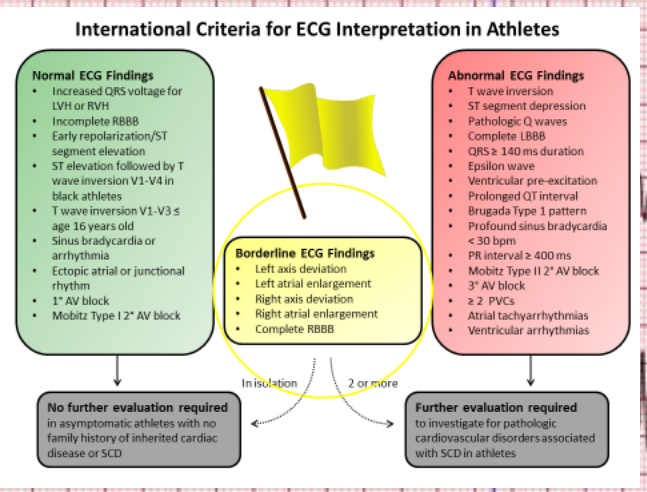
- Large Q wave lead III
- Lack of Q wave in V6
- ST segment depression (not shown)

Ventricular Pre-excitation / Wolff-Parkinson-White pattern

•Short PR <120 ms •Delta waves •Large Q wave lead III • Lack of Q wave in V6



Complete Right Bundle Branch Block

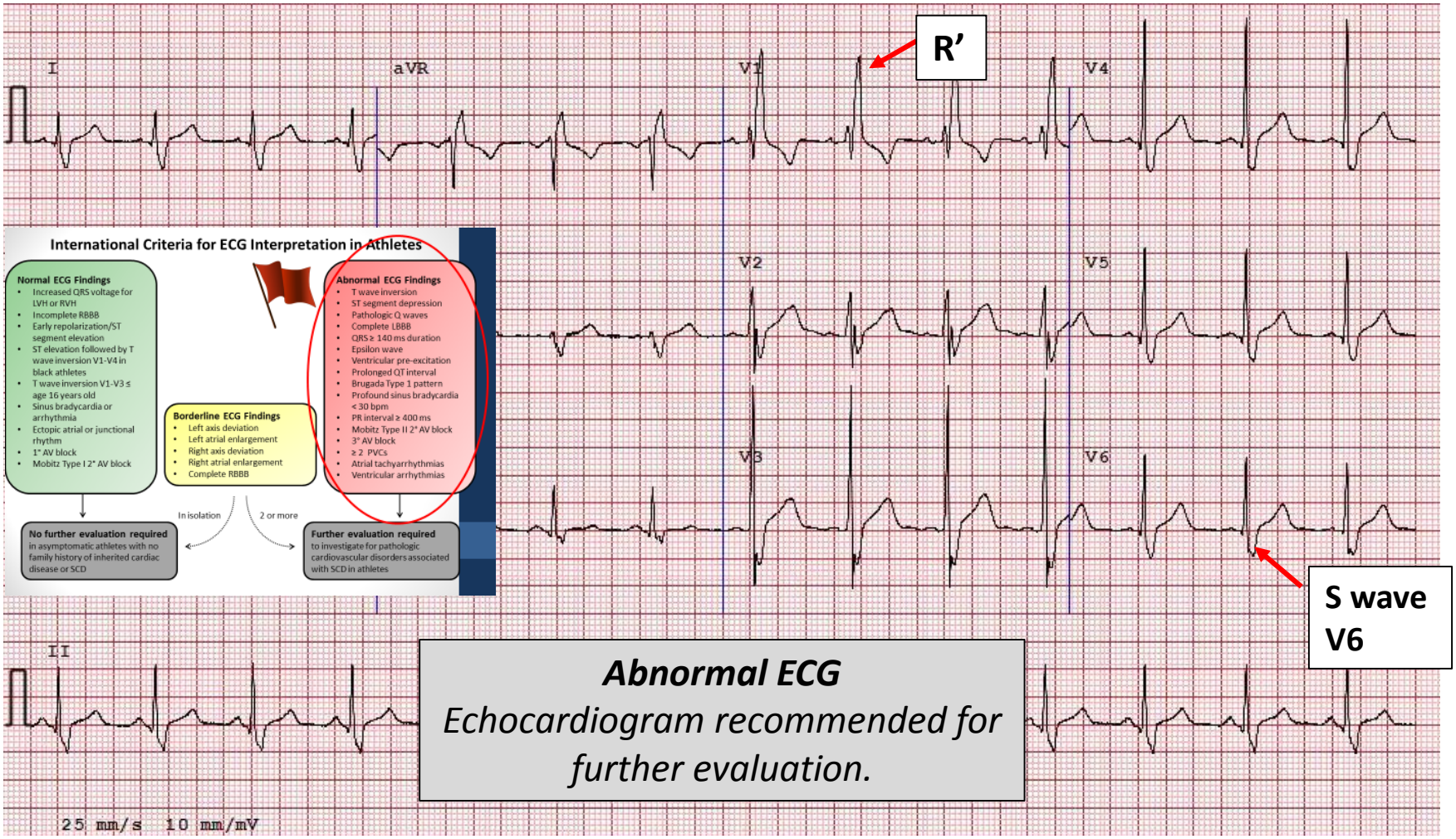


RBBB in Isolation = Normal ECG

- When found in isolation without other borderline or abnormal findings, no further evaluation required

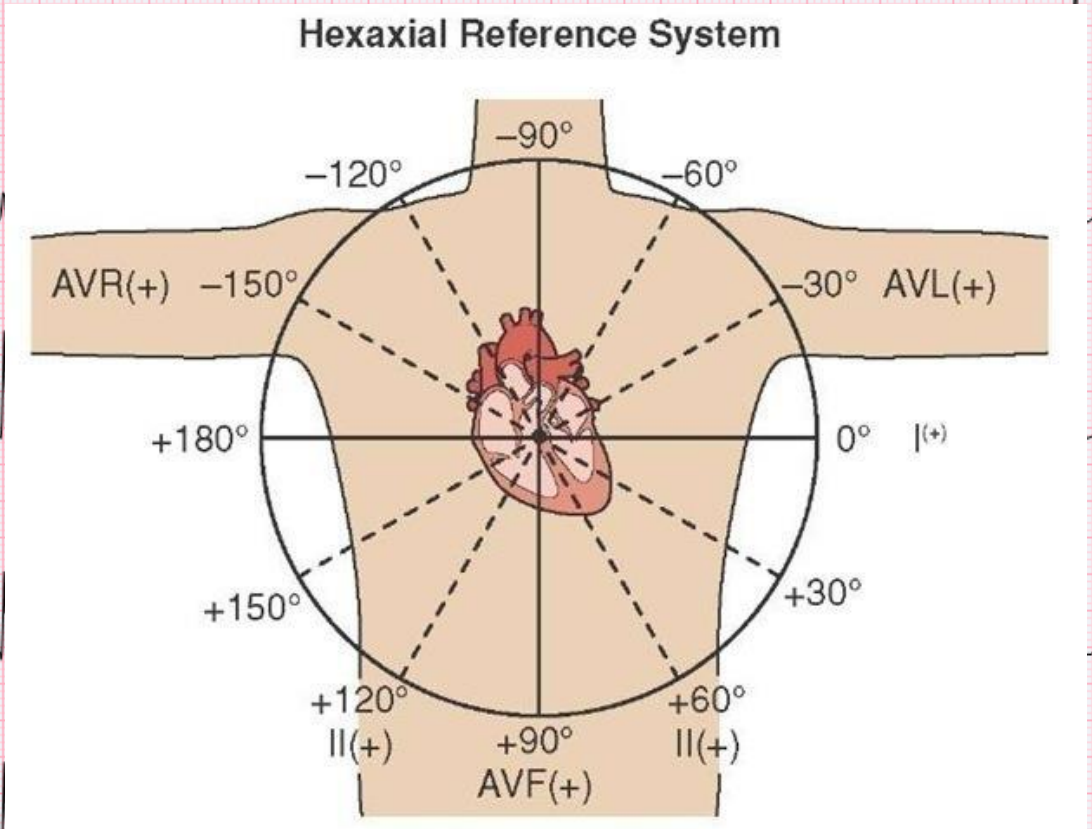
- 19 yo Caucasian male athlete with complete RBBB. The QRS duration is ≥120 ms with rSR' pattern in V1 and S wave wider than R wave in V6.
- When found in isolation without other borderline or abnormal findings, and without other clinical markers of concern, complete RBBB does not require more investigation.

Complete RBBB with QRS Duration ≥ 140 ms = ABNORMAL



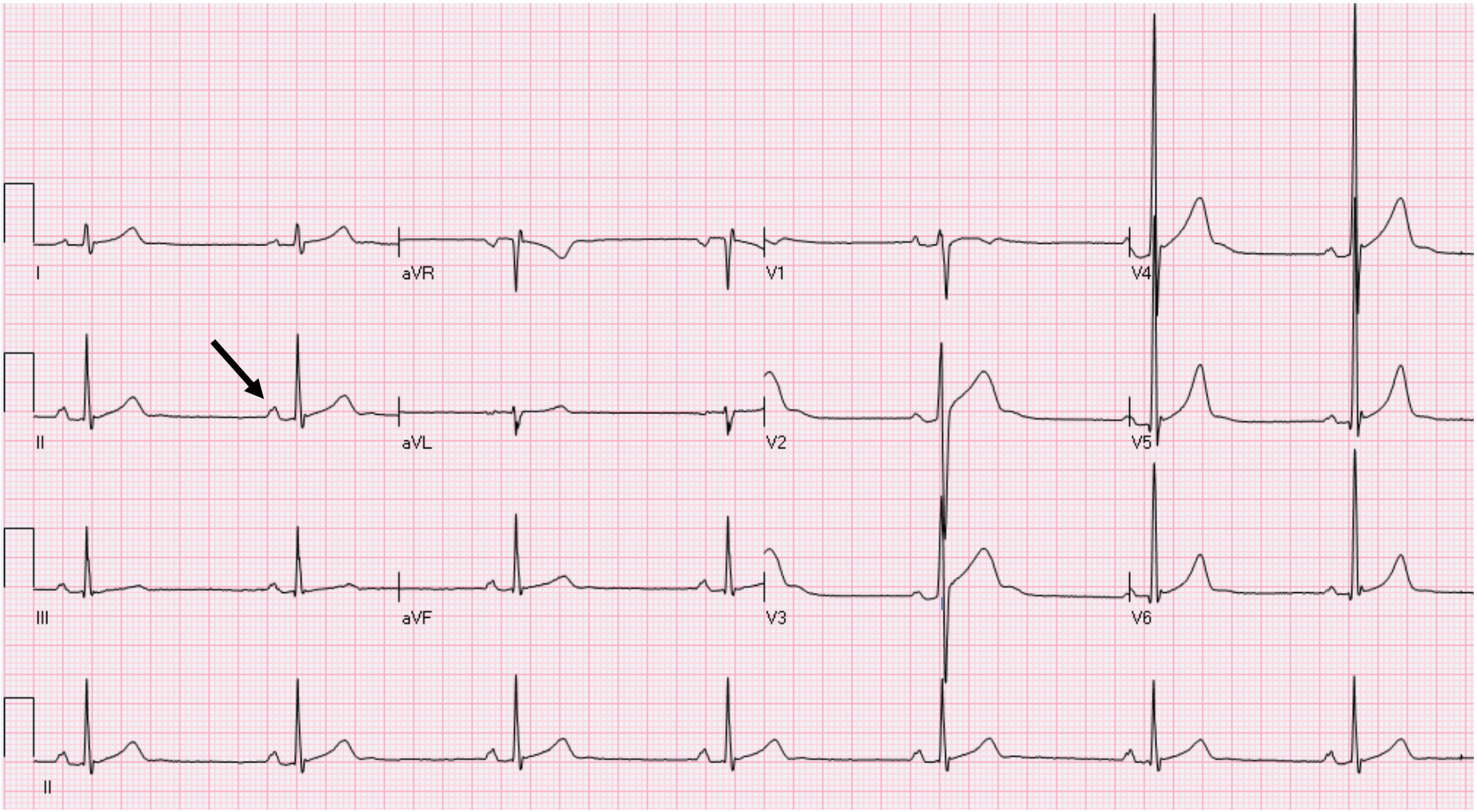
ECG showing complete RBBB with a **QRS duration of 144 ms**. Any conduction delay with QRS duration ≥ 140 ms requires further evaluation.

Step-3: ECG Interpretation in Athletes



Where to look?	What to look for?
3. Axis – limb leads I and II	QRS pos in I and II (leftward to -30°) QRS neg in I and aVR (rightward to 120°)

Step-4: ECG Interpretation in Athletes

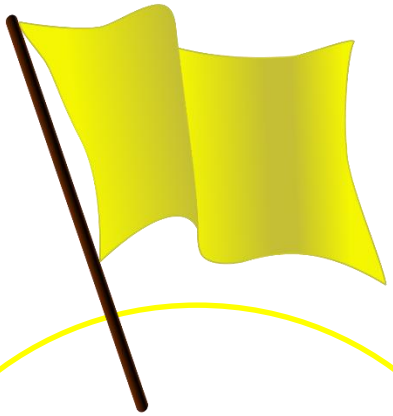


Where to look?	What to look for?
4. Atrial enlargement – P wave in lead II (if needed V1)	LAE: P >120 ms → neg P wave in V1 RAE: P >2.5 mm

International Criteria for ECG Interpretation in Athletes

Normal ECG Findings

- Increased QRS voltage for LVH or RVH
- Incomplete RBBB
- Early repolarization/ST segment elevation
- ST elevation followed by T wave inversion V1-V4 in black athletes
- T wave inversion V1-V3 ≤ age 16 years old
- Sinus bradycardia or arrhythmia
- Ectopic atrial or junctional rhythm
- 1° AV block
- Mobitz Type I 2° AV block



Borderline ECG Findings

- Left axis deviation
- Left atrial enlargement
- Right axis deviation
- Right atrial enlargement
- Complete RBBB

Abnormal ECG Findings

- T wave inversion
- ST segment depression
- Pathologic Q waves
- Complete LBBB
- QRS ≥ 140 ms duration
- Epsilon wave
- Ventricular pre-excitation
- Prolonged QT interval
- Brugada Type 1 pattern
- Profound sinus bradycardia < 30 bpm
- PR interval ≥ 400 ms
- Mobitz Type II 2° AV block
- 3° AV block
- ≥ 2 PVCs
- Atrial tachyarrhythmias
- Ventricular arrhythmias

In isolation

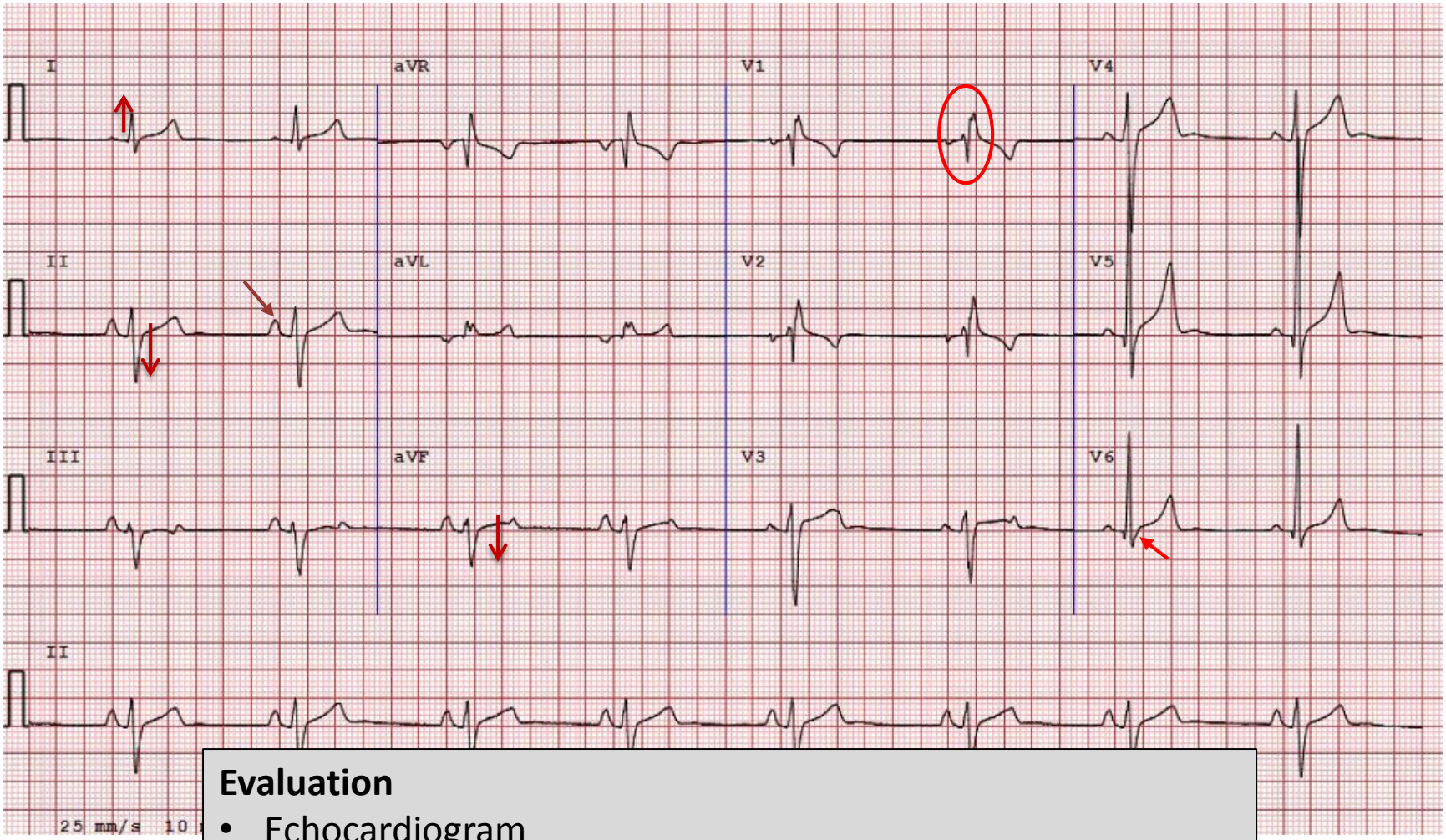
2 or more

No further evaluation required
in asymptomatic athletes with no family history of inherited cardiac disease or SCD

Further evaluation required
to investigate for pathologic cardiovascular disorders associated with SCD in athletes

≥ 2 Borderline Findings = Abnormal ECG

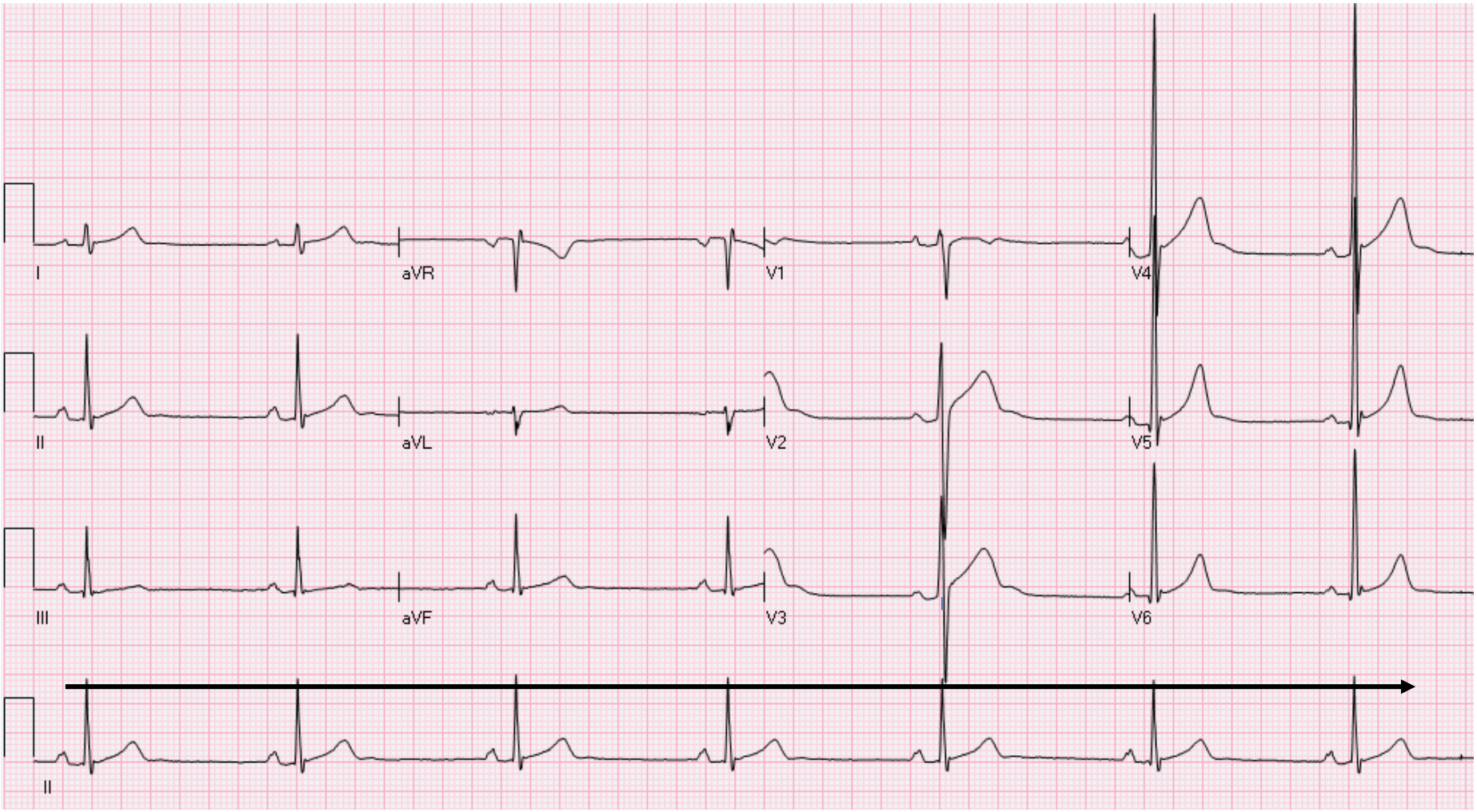
•Complete RBBB •LAD •RAE



Evaluation

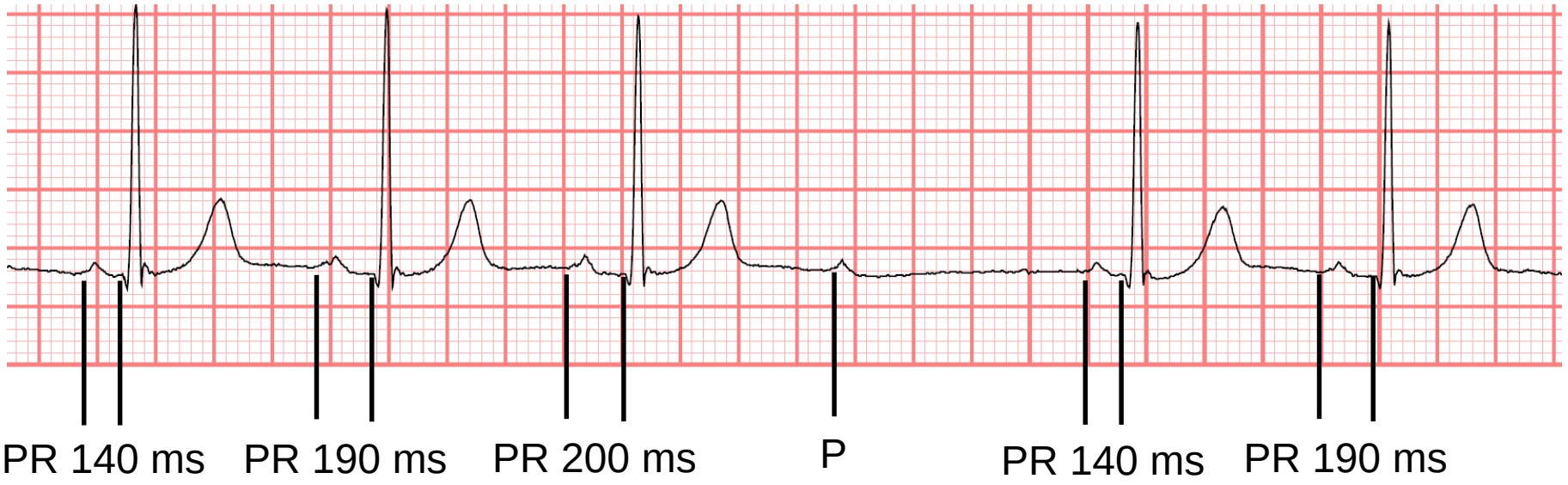
- Echocardiogram
- Consider additional testing based on clinical suspicion

Step-5: ECG Interpretation in Athletes



Where to look?	What to look for?
5. Rhythm strip – lead II or V5	QRS after every P wave Narrow QRS vs PVCs

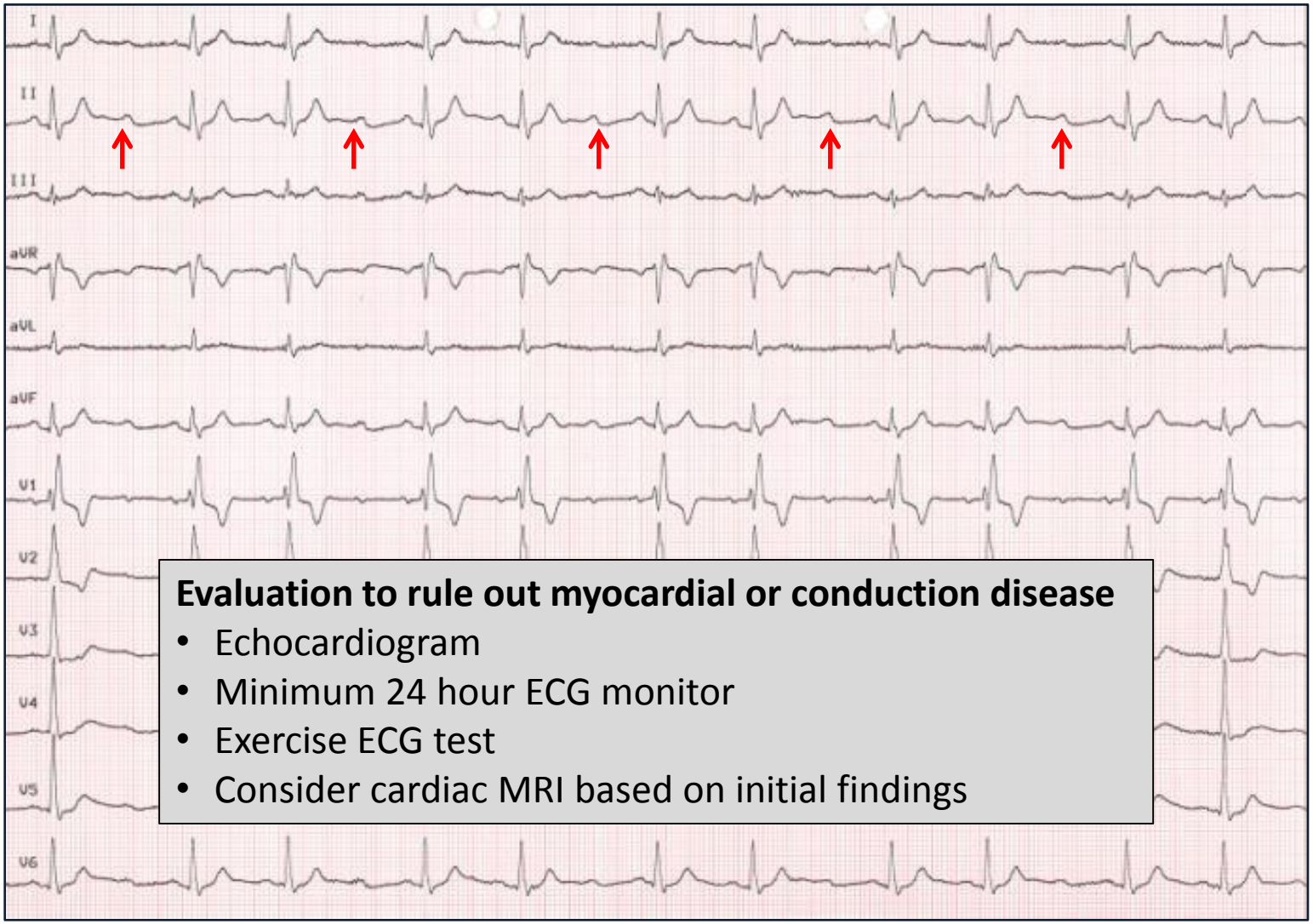
Mobitz Type I (Wenckebach) 2° AV Block



- Mobitz Type I (Wenckebach) 2° AV block is demonstrated by progressively longer PR intervals until there is a non-conducted P-wave and no QRS.
- The first PR interval after the dropped beat is shorter than the last conducted PR interval prior to the dropped beat

Mobitz Type II 2nd Degree AV Block

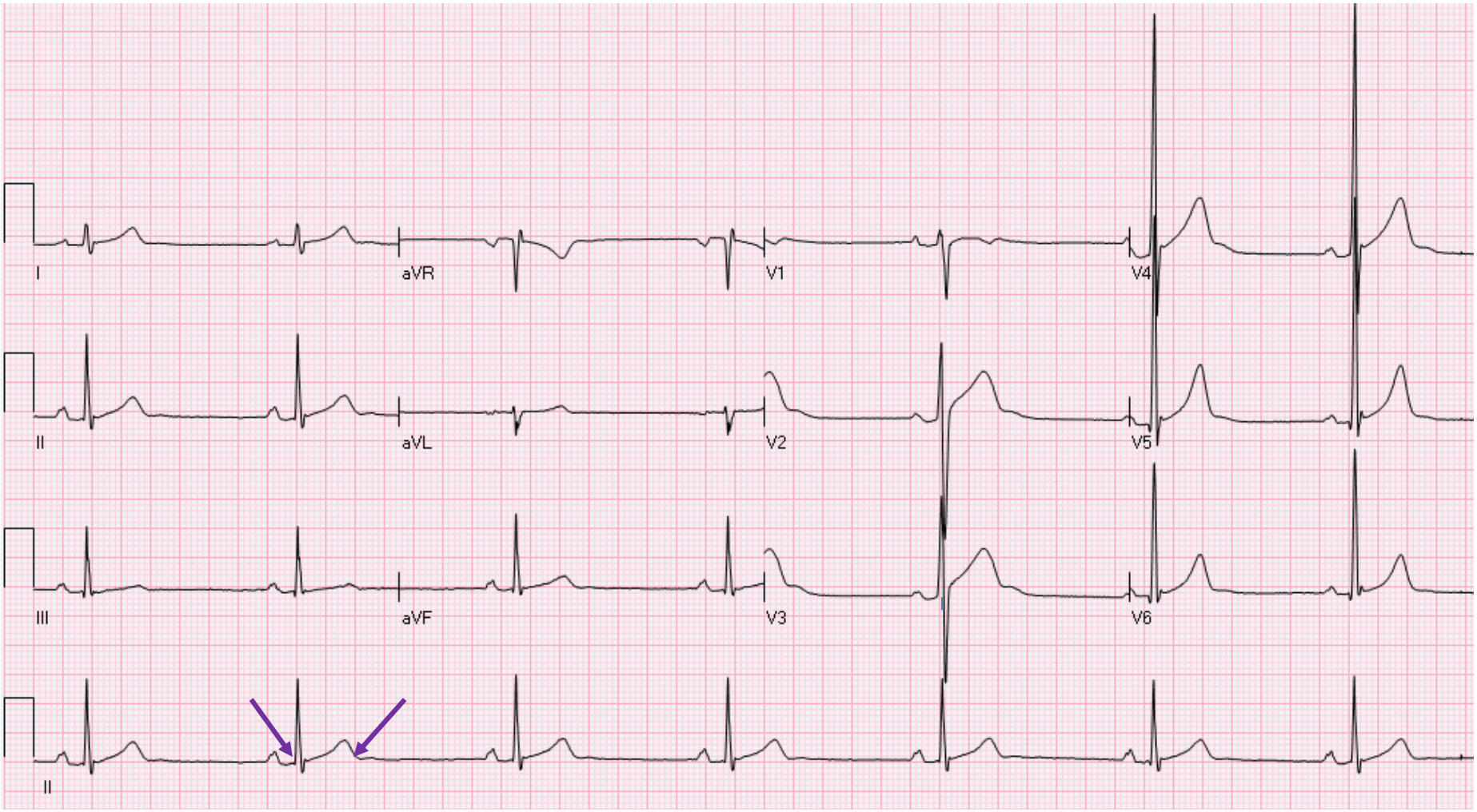
- P waves with loss of conduction and no QRS complex (arrows)
- No PR prolongation in the beats prior, nor PR shortening in the beats after (i.e. not Mobitz type I)



Evaluation to rule out myocardial or conduction disease

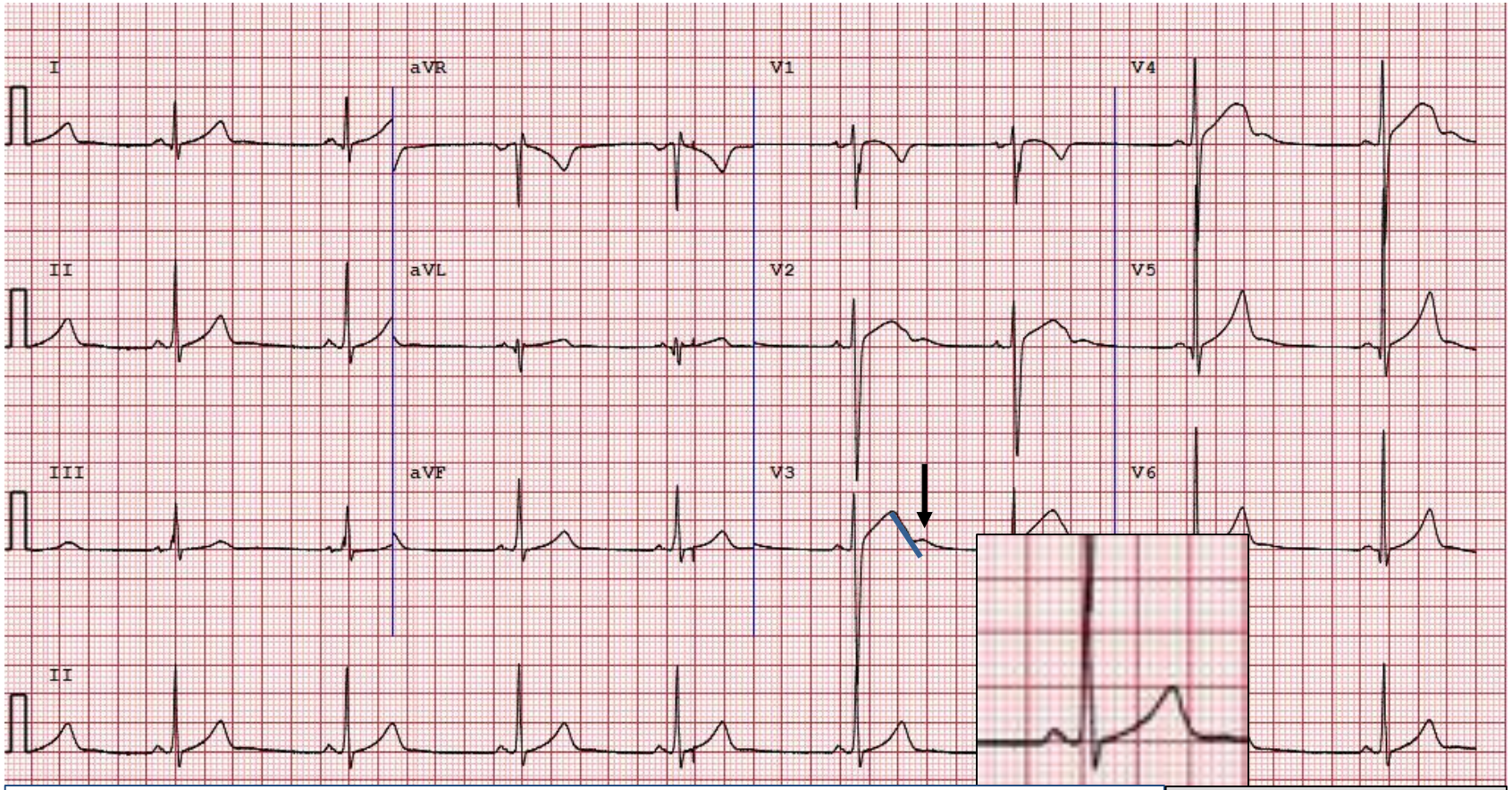
- Echocardiogram
- Minimum 24 hour ECG monitor
- Exercise ECG test
- Consider cardiac MRI based on initial findings

Step-6: ECG Interpretation in Athletes



Where to look?	What to look for?
6. QT interval – lead II or V5	QTc ≥470 ms males or ≥480 ms females

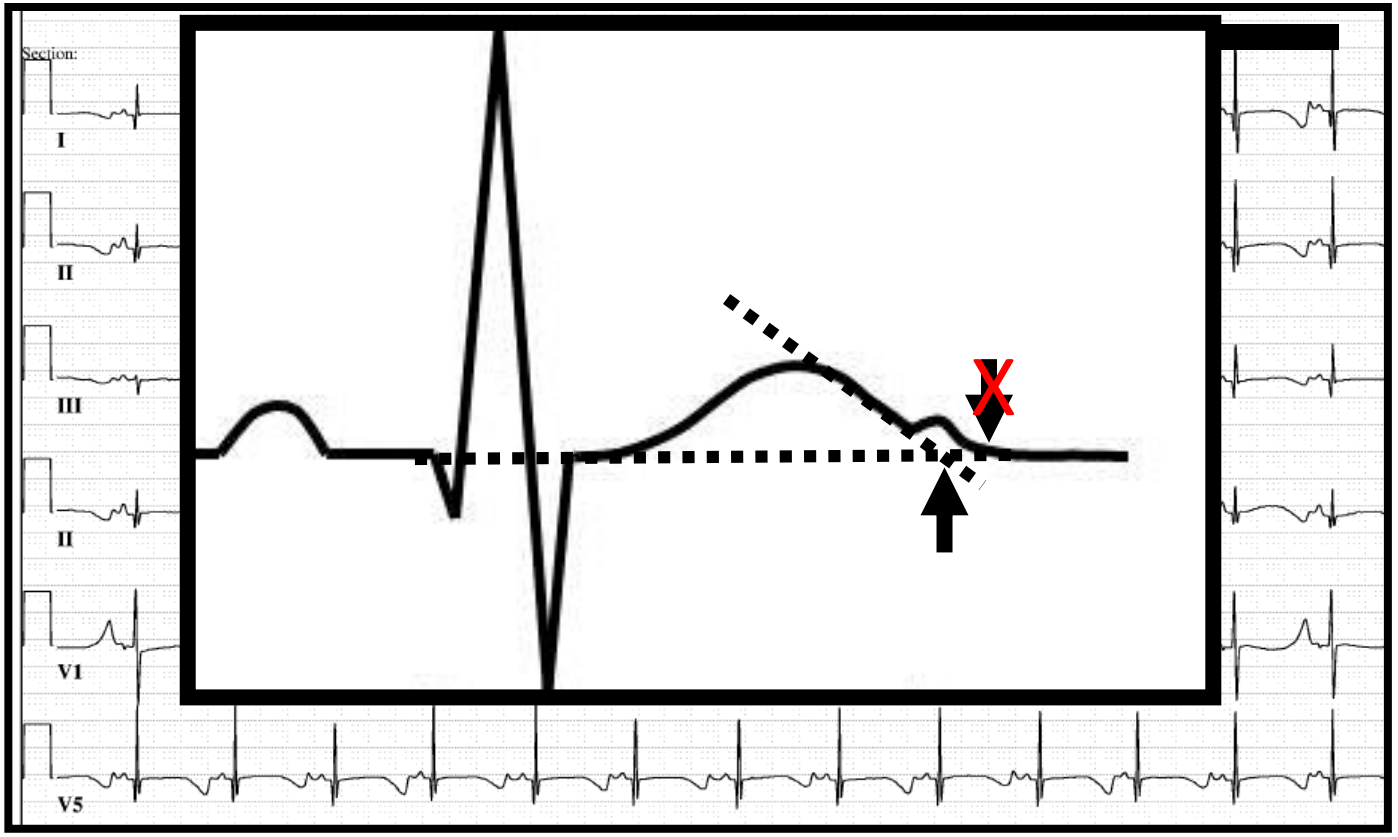
Long QT Syndrome?



Normal ECG

- QTc is normal
- Don't include the U wave in anterior precordial leads!
  - "Teach-the-tangent" or "Avoid-the-tail" method for manual measurement of the QT interval

No further evaluation needed

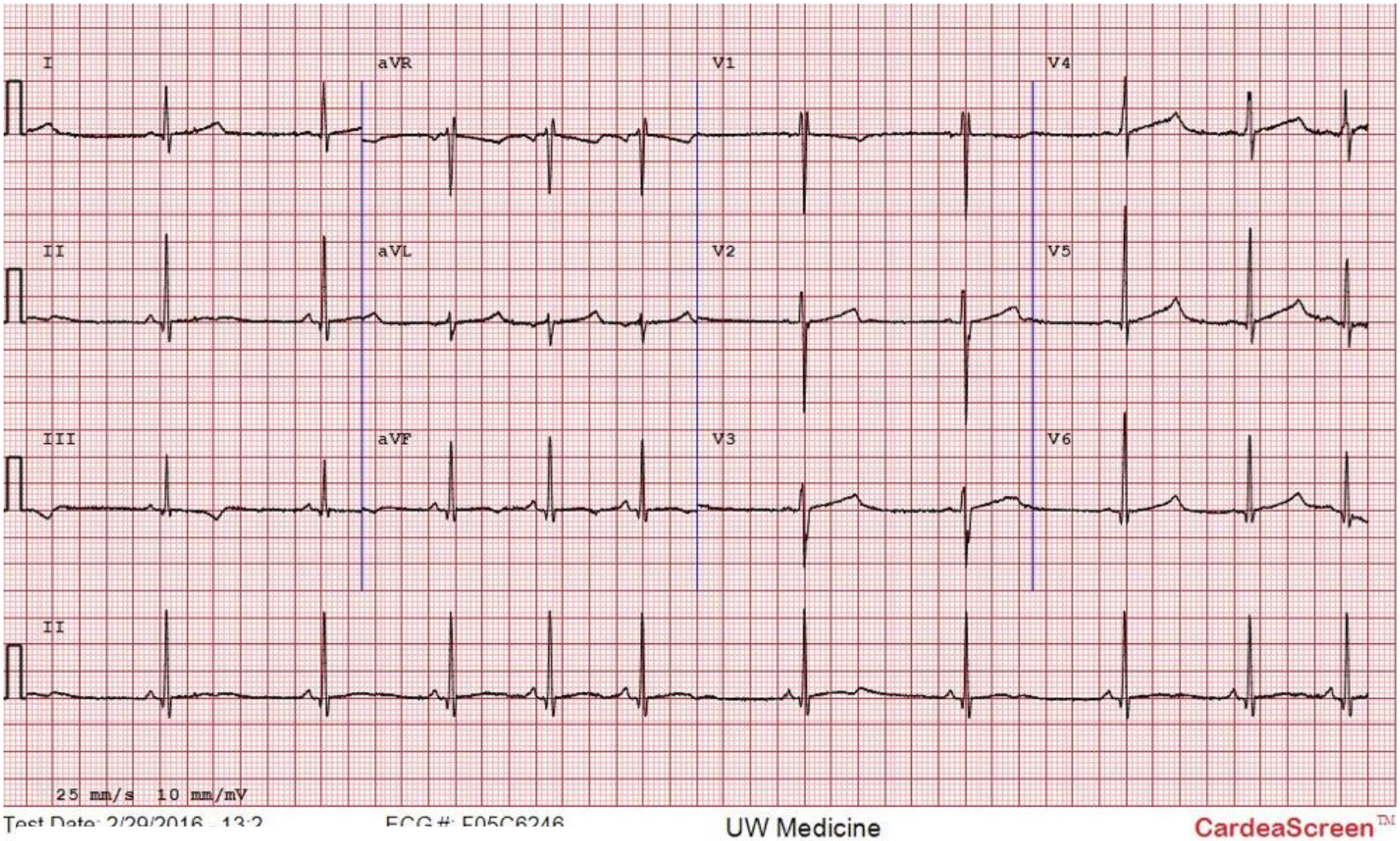


This figure illustrates the “Teach-the-Tangent” or “Avoid-the-Tail” method for manual measurement of the QT interval. A straight line is drawn on the downslope of the T wave to the point of intersection with the isoelectric line. The U wave is not included.

- **Bazett’s formula**: QTc = QT/√RR
  - Inaccurate at heart rates < 50 or > 90 bpm
  - QT interval will equal the QTc at a heart rate of 60 bpm
- Use **lead II or V5** where the end of the T wave is readily delineated
- Abnormal QTc is considered ≥470 ms in males and ≥480 ms in females

Normal or Abnormal?

14 yo Caucasian female elite soccer player



Abnormal 'notched' T Wave morphology suggests LQT-2

Average QT interval ~500 ms

COVID-19 Pandemic

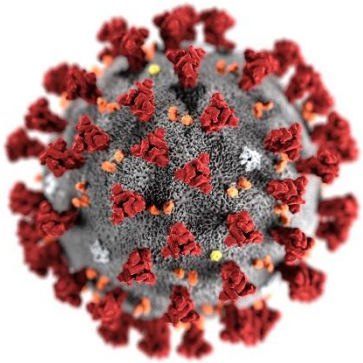
Cardiac Implications of COVID-19

JAMA Cardiology | Original Investigation

Association of Cardiac Injury With Mortality in Hospitalized Patients With COVID-19 in Wuhan, China

Shaobo Shi, MD; Mu Qin, MD; Bo Shen, MD; Yuli Cai, MD; Tao Liu, MD; Fan Yang, MD; Wei Gong, MMSC; Xu Liu, MD, PhD; Jinjun Liang, MD, PhD; Qinyan Zhao, MD, PhD; He Huang, MD, PhD; Bo Yang, MD, PhD; Congxin Huang, MD, PhD

28% of hospitalized patients with COVID-19 had myocardial injury



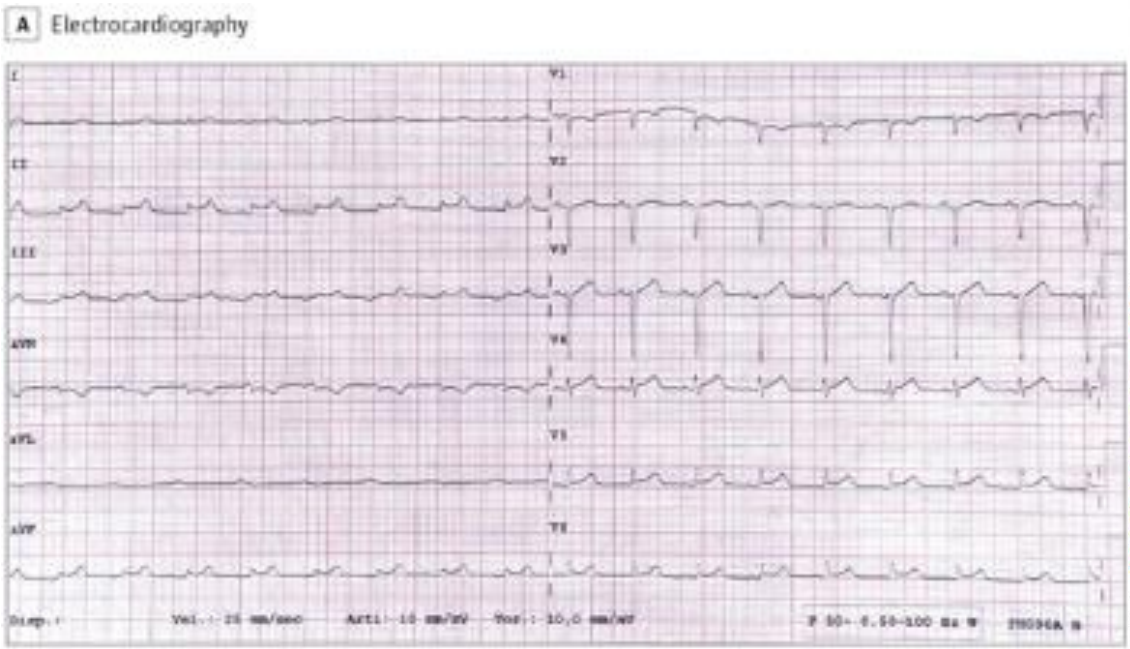
Brief Report

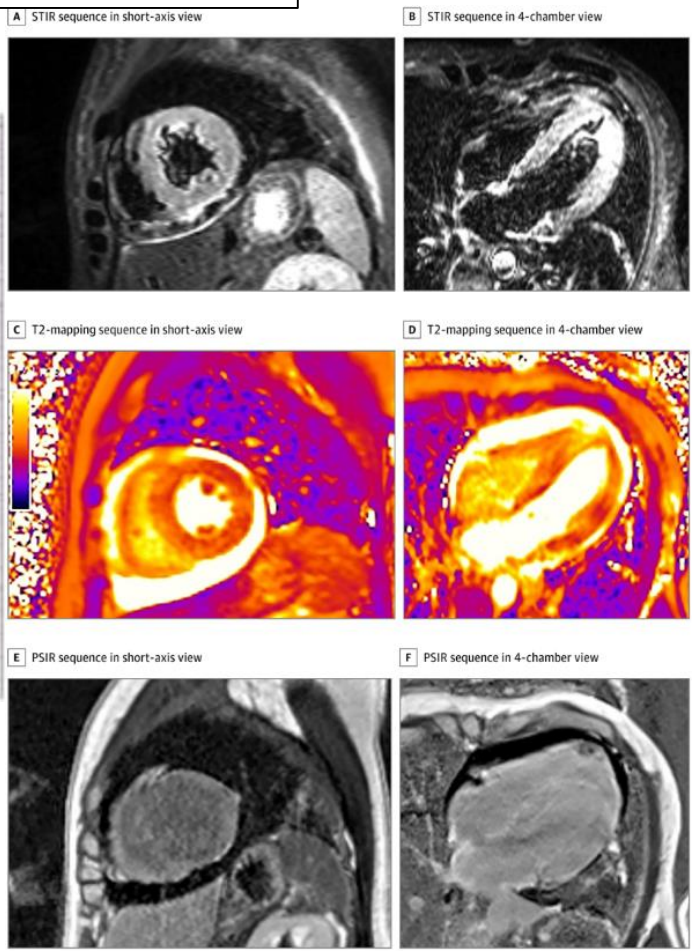
ONLINE FIRST

March 27, 2020

Cardiac Involvement in a Patient With Coronavirus Disease 2019 (COVID-19)

Riccardo M. Inciardi, MD[1]; Laura Lupi, MD[1]; Gregorio Zaccone, MD[1]; et al





53 yo F presenting with severe fatigue one week after fever and dry cough. Elevated high-sensitivity troponin and NT-proBNP levels. LVEF 35%.

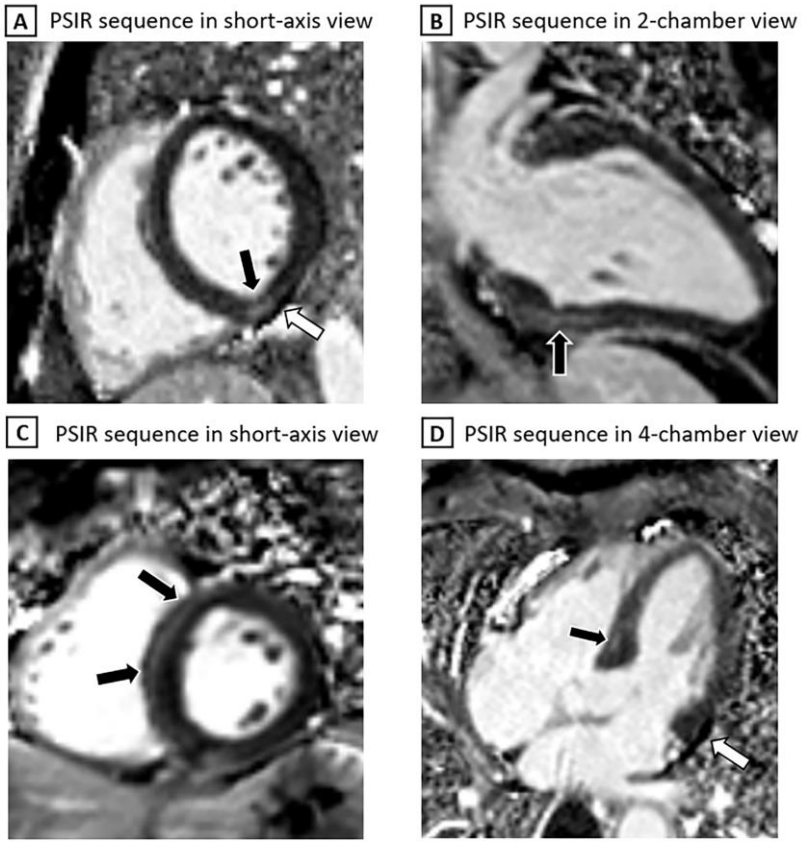
Journal Pre-proof

JACC Cardiovascular Imaging

Cardiac involvement in recovered COVID-19 patients identified by magnetic resonance imaging

Lu Huang, MD, PHD, Peijun Zhao, MD, Dazhong Tang, MS, Tong Zhu, MD, Rui Han, MD, Chenao Zhan, MD, PHD, Weiyong Liu, MD, PHD, Hesong Zeng, MD, PHD, Qian Tao, PHD, Liming Xia, MD, PHD

54% of previously hospitalized patients (mean age 38 years) with ongoing symptoms had myocardial edema on cardiac MRI



Blog | British Journal of Sports Medicine

The resurgence of sport in the wake of COVID-19: cardiac considerations in competitive athletes

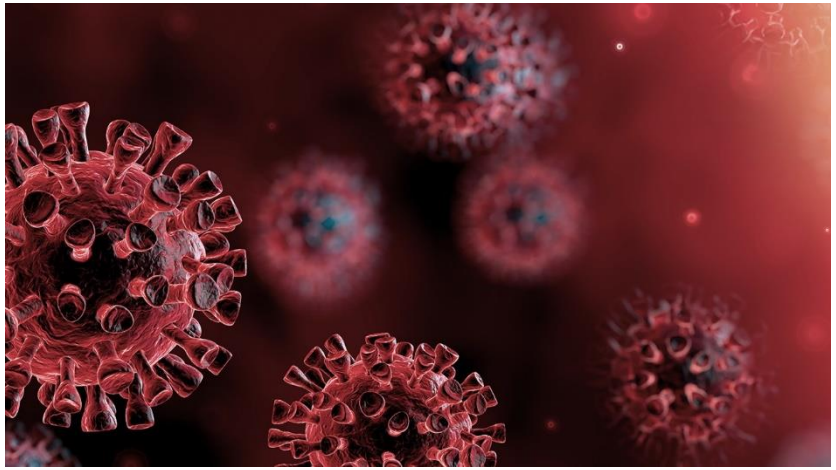
Posted on April 24, 2020 by BJSM

848

By Aaron L. Baggish, MD, Jonathan A. Drezner, MD, Jonathan H. Kim, MD, MSc, Matthew W. Martinez, MD, Jordan M. Prutkin, MD, MHS

Table 1. Cardiac Evaluation in Athletes with Prior COVID-19 Infection

Clinical Scenario	Recommended Assessment	Comments
Athletes with **prior asymptomatic infection** as confirmed antibody to SARS-Coronavirus-2	Focused Medical History and Physical Examination to screen for findings newly emergent in the COVID-19 era. **Consider 12-lead ECG*** • If ECG is abnormal or shows new repolarization changes compared to a prior ECG, then additional evaluation with at minimum an echocardiogram and exercise test is warranted in conjunction with a sports cardiologist.	• Myopericarditi… COVID-19 sho… considered in p… history of new … pain/pressure (… absence of feve… respiratory sym… palpitations, or… intolerance. • Comprehensive clinical evaluation, regardless of ECG findings, is indicated in athletes with new onset cardiovascular symptoms or exercise intolerance.
Athletes with a **history of mild illness (non-hospitalized)** related to confirmed or suspected COVID-19	Focused Medical History and Physical Examination to screen for persistent or new post-infectious findings following COVID-19 infection. **Perform 12-lead ECG*** • If ECG is abnormal or shows new repolarization changes compared to a prior ECG, then additional individualized evaluation is warranted, including at minimum echocardiography and exercise testing, in conjunction with a sports cardiologist.	• **ECG findings** that may indicate viral-induced myocardial injury include: pathological Q waves, ST segment depression, (new) diffuse ST segment elevation, and T-wave inversion. • Comprehensive clinical evaluation, regardless of ECG findings, is indicated in athletes with new onset cardiovascular symptoms or exercise intolerance.
Athletes with a **history of moderate to severe illness (hospitalized)** related to confirmed or suspected COVID-19	**Comprehensive evaluation** prior to return to sport, in conjunction with a sports cardiologist, to include blood biomarker assessment (i.e. hs-Tn, NP), 12-lead ECG, echocardiography, exercise testing, and ambulatory rhythm monitoring.	• **Myocardial injury is more likely in patients with a more severe disease** course, and normal cardiac function and exercise tolerance should be established prior to a return to exercise. • Cardiac MRI may be considered based on clinical suspicion of myocardial injury.**



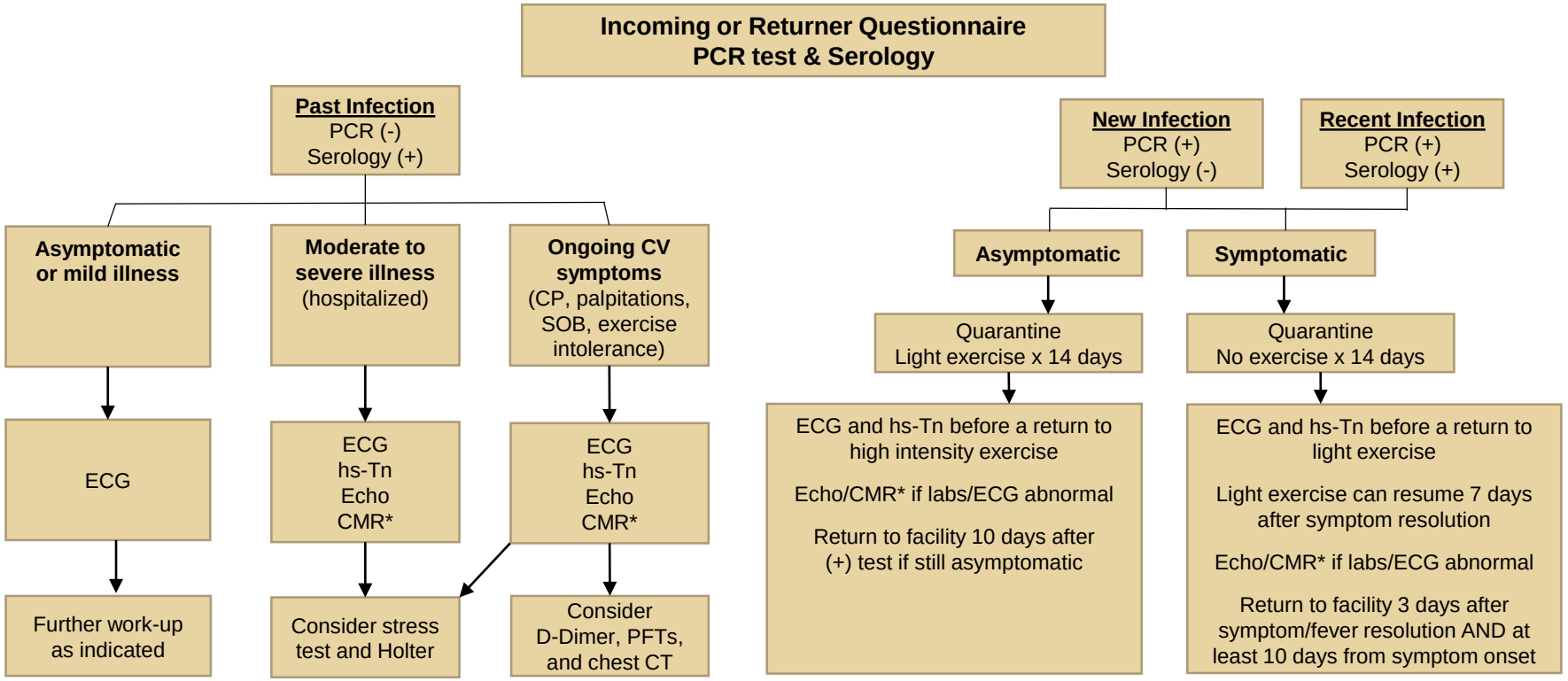
https://blogs.bmj.com/bjsm/2020/04/24/the-resurgence-of-sport-in-the-wake-of-covid-19-cardiac-considerations-in-competitive-athletes/

COVID-19 and return to sport:

Cardiac Considerations for athletes

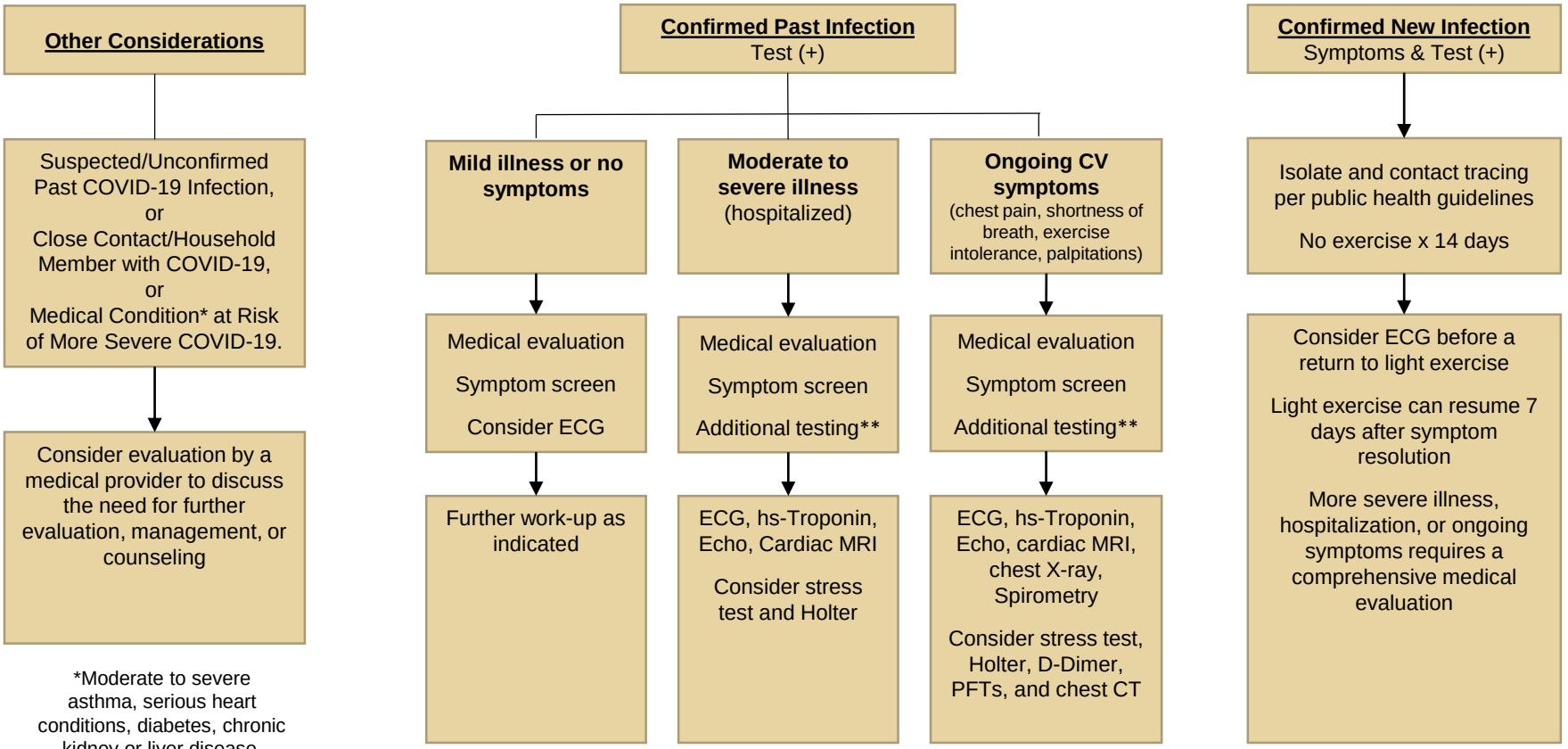
Infographic by Bridie Nanai

University of Washington Intercollegiate Athletics COVID-19 Algorithm

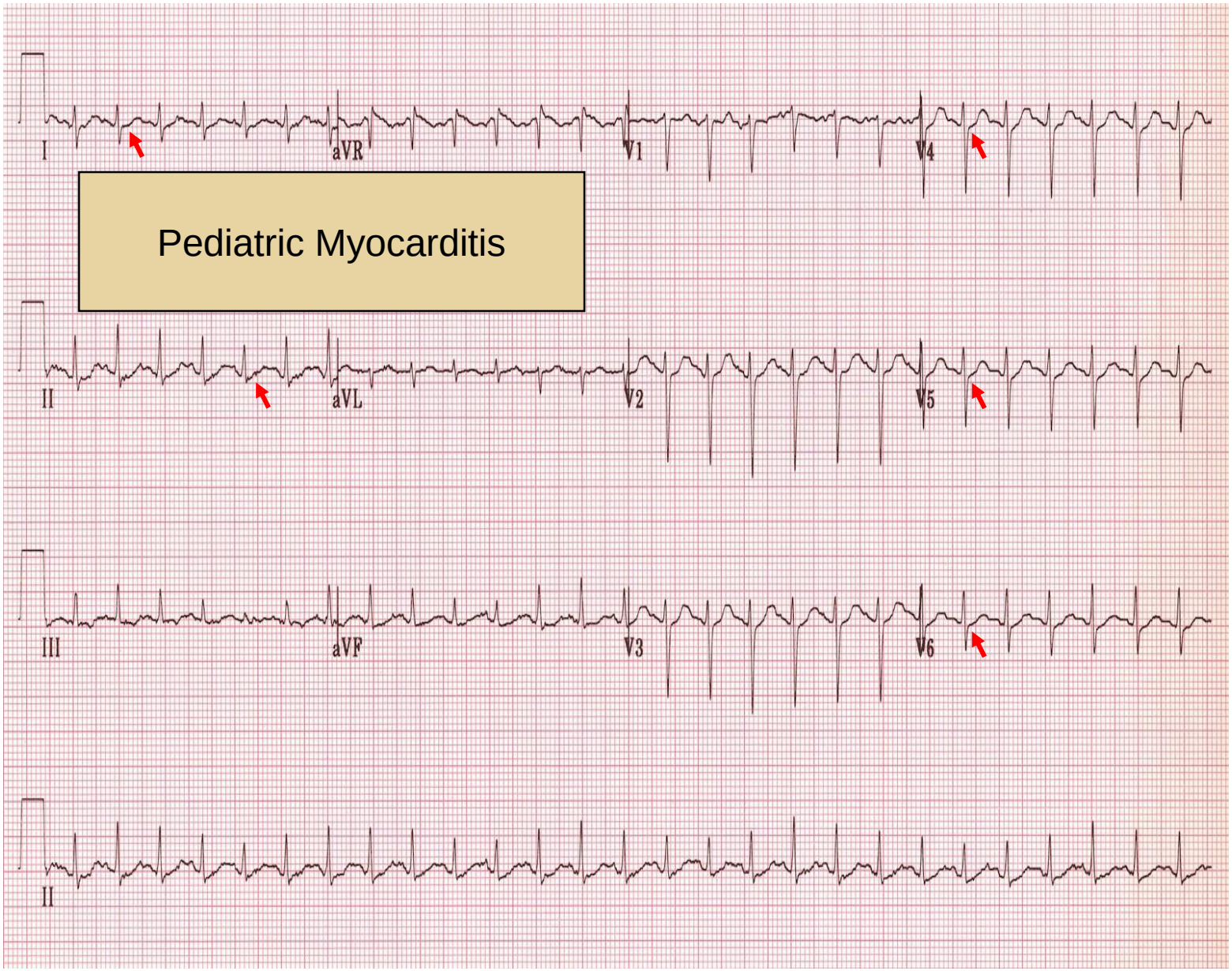


*Confirmed myocarditis is managed per guidelines with cardiology consultation

Cardiopulmonary Considerations for Student-Athletes during the COVID-19 Pandemic

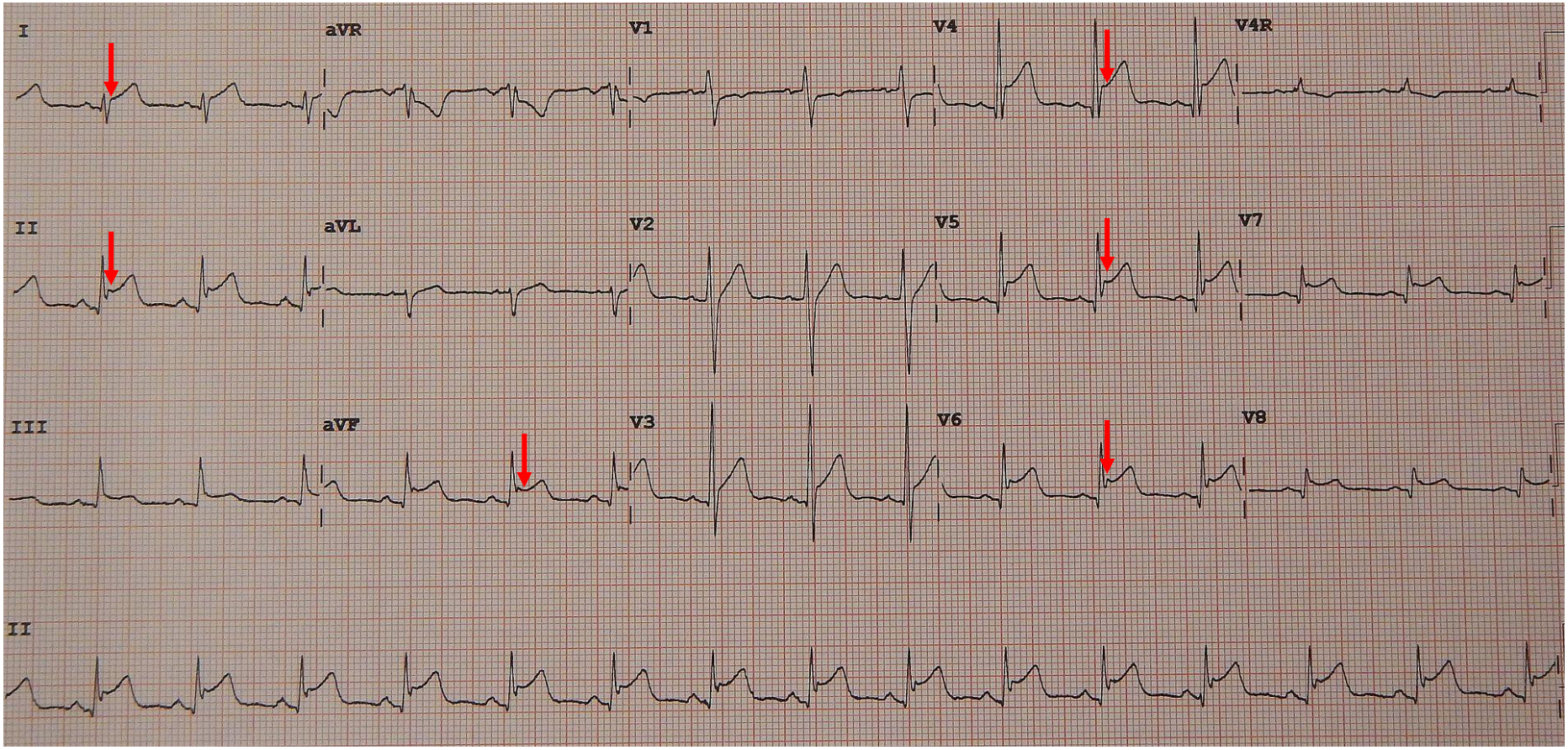


Normal or Abnormal?



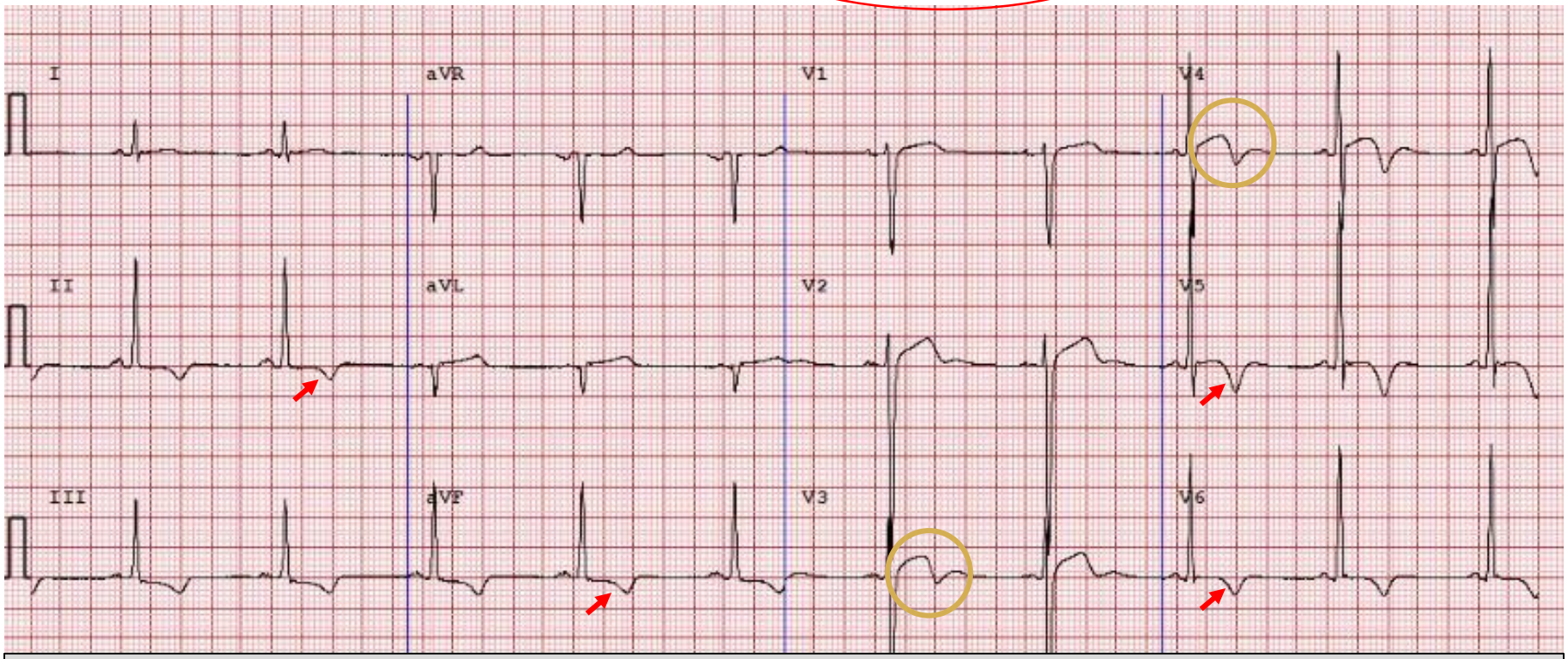
Pediatric Myocarditis

Normal or Abnormal?



Wikipedia – Myocarditis

Normal or Abnormal?



Evaluation of Inferolateral TWI

Additional testing to rule out cardiomyopathy

- Echo
- Cardiac MRI
- Holter + stress testing for ‘grey zone’ findings
- If initial studies are non-diagnostic → serial (annual) follow-up with ECG + Echo (at minimum); cardiac MRI for changes in ECG or Echo

AUSTRALASIAN COLLEGE OF
SPORT AND EXERCISE PHYSICIANS

UW Medicine
Center For Sports Cardiology

ECG INTERPRETATION IN ATHLETES

1. Basic ECG Interpretation in Athletes
2. Normal ECG Findings in Athletes
3. ECG Abnormalities in Cardiomyopathy
4. ECG Abnormalities in Primary Electrical Disease
5. ECG Interpretation Challenges & Common Pitfalls
6. ECG Interpretation Challenges & Common Pitfalls

The Center for Sports Cardiology at the University of Washington in collaboration with the Australasian College of Sport and Exercise Physicians are extremely excited to offer open access worldwide to a new collection of six online ECG training modules. These are based on the 'International criteria' and the latest consensus recommendations for ECG interpretation in athletes.

To access the free ECG training modules, go to:
www.uwsportscardiology.org/E-Academy

ECG INTERPRETATION IN ATHLETES
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MODULE 1 — Basic ECG interpretation in athletes — POST TEST

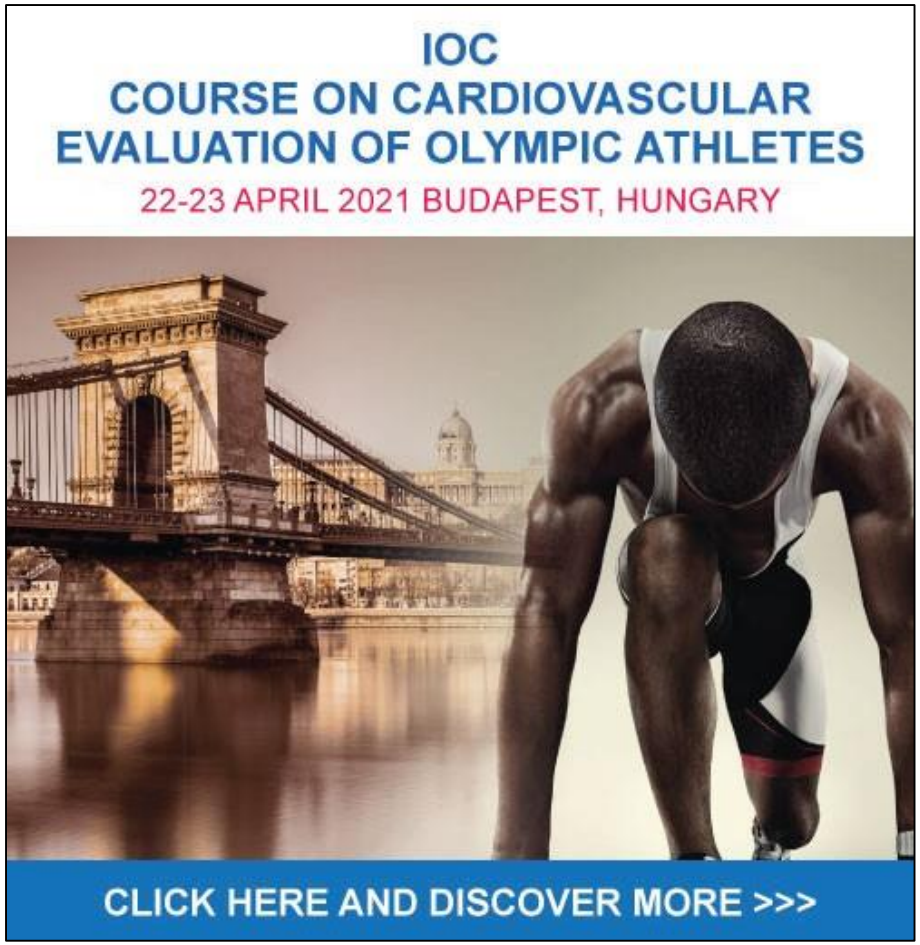
MODULE 2 — Normal physiologic ECG findings in athletes

MODULE 3 — ECG abnormalities in cardiomyopathy

MODULE 4 — ECG abnormalities in primary electrical disease

MODULE 5 — ECG interpretation challenges and pitfalls

MODULE 6 — Advanced ECG interpretation in athletes — POST TEST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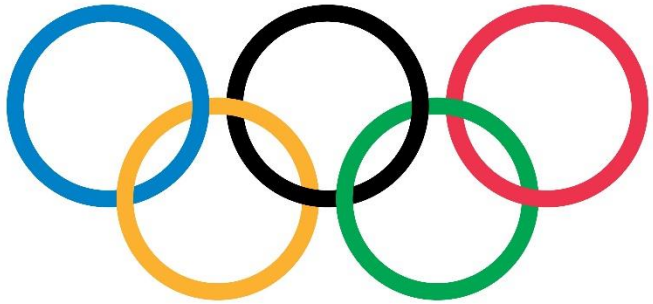

TAKE HOME POINTS

1. Follow the International Criteria recommendations for ECG interpretation and the secondary evaluation of ECG abnormalities
2. Consider “6-steps” for accurate ECG interpretation in athletes
3. Lateral or inferolateral TWI requires a contrast-enhanced cardiac MRI
4. Serial cardiac imaging is required for athletes with markedly abnormal ECGs and normal cardiac imaging
5. Past infection with COVID-19 increases the risk of myocarditis; review of ongoing symptoms and severity of illness should guide the extent of cardiac evaluation

https://uwsportscardiology.org/e-academy/