Evolution of Athlete Specific ECG Criteria

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Conflicts: None

Athletic Affiliations:

Funding Sources:

- National Institutes of Health
- American Heart Association
- American Society of Echocardiography
- Department of Defense
- National Football League Player's Association

A Teaching Affiliate of Harvard Medical School

ECG Criteria: An Evolution

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Criteria (O.E.D.): A list of principles or standards by which something may be judged or decided

-Ubiquitous in medicine & science….A.U.C.

-Provide standardization across time, space, and level of expertise

-Starting point for diagnostic decision making

-They are imperfect and only as good as the data & experience that generate them

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The New England Journal of Medicine

SCREENING FOR HYPERTROPHIC CARDIOMYOPATHY IN YOUNG ATHLETES

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ABSTRACT

Background For more than 20 years in Italy, young athletes have been screened before participating in competitive sports. We assessed whether this strategy results in the prevention of sudden death from hypertrophic cardiomyopathy, a common cardiovascular cause of death in young athletes.

Methods We prospectively studied sudden deaths among athletes and nonathletes (35 years of age or less) in the Veneto region of Italy from 1979 to 1996. The causes of sudden death in both populations were compared, and the pathological findings in the athletes were related to their clinical histories and electrocardiograms. Cardiovascular reasons for disqualification from participation in sports were investigated and follow-up was performed in a consecutive series of 33,735 young athletes who underwent preparticipation screening in Padua, Italy, during the same period.

Results Of 269 sudden deaths in young people, 49 occurred in competitive athletes (44 male and 5 female athletes; mean [±SD] age, 23±7 years). The most common causes of sudden death in athletes were arrhythmogenic right ventricular cardiomyopathy (22.4 percent), coronary atherosclerosis (18.4 percent), and anomalous origin of a coronary artery (12.2 percent). Hypertrophic cardiomyopathy caused only 1 sudden death among the athletes (2.0 percent) but caused 16 sudden deaths in the nonathletes (7.3 percent). Hypertrophic cardiomyopathy was detected in 22 athletes (0.07 percent) at preparticipation screening and accounted for 3.5 percent of the cardiovascular reasons for disqualification. None of the disqualified athletes with hypertrophic cardiomyopathy died during a mean follow-up period of 8.2±5 years.

Conclusions The results show that hypertrophic cardiomyopathy was an uncommon cause of death in these young competitive athletes and suggest that the identification and disqualification of affected athletes at screening before participation in competitive sports may have prevented sudden death. (N Engl J Med 1998;339:364-9.)

MOST sudden deaths in athletes are due to cardiovascular disease.[1-10] Atherosclerotic coronary artery disease is the most common cause of sudden death in athletes over 35 years of age.[2,4,5] Hypertrophic cardiomyopathy has been implicated as the principal cause of cardiac arrest in younger competitive athletes, accounting for about one third of fatal cases in the United States.[2,7-9] The early identification of this abnormality by screening of athletes before they participate in competitive sports might prevent sudden death, but the cost effectiveness of this strategy is still controversial.[11,12] A national program for systematic preparticipation screening of all young competitive athletes has been in place in Italy for more than 20 years. The present study addressed the effects of this strategy in terms of the prevention of sudden death from hypertrophic cardiomyopathy in the Veneto region of Italy.

METHODS

Since 1971 Italian law has required that every athlete undergo an annual clinical evaluation to obtain approval to participate in competitive sports.[13-15] We evaluated the effects of this community-based screening strategy through a prospective investigation of the causes of sudden death in both competitive athletes and nonathletes 35 years of age or younger in the Veneto region of Italy from 1979 to 1996 and an assessment of the cardiovascular reasons for disqualification in a large series of young competitive athletes who underwent preparticipation screening during this time in the Padua area. A competitive athlete was defined as "a participant in an organized sports program requiring regular training and competition."[9]

Sudden Death in Young Athletes and Nonathletes

The Veneto region of Italy covers an area of 18,368 km². During the study period, the population was stable and averaged 4,379,900, according to census data. There were 2,009,600 persons 35 years of age or less, defined as "young" in this paper. Nearly all residents were white, and the population was ethnically homogeneous. According to the Sports Medicine Data Base of the Veneto region, the rate of participation in competitive athletics among young people was 9.6 percent.

A prospective clinicopathological study of sudden death in young people has been carried out in the Veneto region since 1979.[16] The sudden infant death syndrome was excluded from this investigation. The medical centers participating in this project (see the Appendix) serve 94.4 percent of the population. In all cases of sudden death in young people that occurred from 1979 to 1996, an autopsy was carried out by the local pathologist or medical examiner at one of these medical centers. Sudden death was defined as unexpected death occurring as a result of natural causes in which loss of all functions occurred instantaneously or within six hours of the onset of symptoms or collapse. After noncardiac causes of death were ruled out, all the hearts were fixed in formalin and forwarded to the Institute of Pathological Anatomy of the University of Padua for detailed morphologic assessment, according to a previously described protocol.[16] The subject's clinical history and athletic activity and the circumstances surrounding the cardiac arrest were investigated in each case. Causes of sudden death in competitive athletes and nonathletes were compared to assess which conditions were significantly associated with

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TABLE 1. CRITERIA FOR A POSITIVE 12-LEAD ELECTROCARDIOGRAM.*

P wave

Left atrial enlargement: negative portion of the P wave in lead V_1 ≥0.1 mV in depth and ≥0.04 sec in duration

Right atrial enlargement: peaked P wave in leads II and III or V_1 ≥0.25 mV in amplitude

QRS complex

Frontal-plane axis deviation: right ≥+120 degrees or left −30 degrees to −90 degrees

Increased voltage: amplitude of R or S wave in a standard lead ≥2 mV, S wave in lead V_1 or V_2 ≥3 mV, or R wave in lead V_5 or V_6 ≥3 mV

Abnormal Q waves ≥0.04 sec in duration or ≥25 percent of the height of the ensuing R wave, or QS pattern in two or more leads

Right or left bundle-branch block with QRS duration ≥0.12 sec

R or R′ wave in lead V_1 ≥0.5 mV in amplitude and R:S ratio ≥1

ST segment, T waves, and QT interval

ST-segment depression or T-wave flattening or inversion in two or more leads

Prolongation of QT interval corrected for the heart rate >0.44 sec

Rhythm and conduction abnormalities

Premature ventricular beats or more severe ventricular arrhythmia

Supraventricular tachycardia, atrial flutter, or atrial fibrillation

Short PR interval (<0.12 sec) with or without delta wave

Sinus bradycardia with resting heart rate ≤40 beats per minute and increasing to <100 beats per minute during limited exercise testing

First-degree (PR ≥0.21 sec, not shortening with hyperventilation or limited exercise testing), second-degree, or third-degree atrioventricular block

*The criteria are from Friedman,[17] Romhilt and Estes,[18] Morris et al.,[19] and Savage et al.[20]

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ESC Report

Cardiovascular pre-participation screening of young competitive athletes for prevention of sudden death: proposal for a common European protocol

Table 3 Criteria for a positive 12-lead ECG

P wave
- left atrial enlargement: negative portion of the P wave in lead V1 ≥ 0.1 mV in depth and ≥0.04 s in duration;
- right atrial enlargement: peaked P wave in leads II and III or V1 ≥ 0.25 mV in amplitude.

QRS complex
- frontal plane axis deviation: right ≥ + 120° or left −30° to −90°;
- increased voltage: amplitude of R or S wave in in a standard lead ≥2 mV, S wave in lead V1 or V2 ≥ 3 mV, or R wave in lead V5 or V6 ≥ 3 mV;
- abnormal Q waves ≥0.04 s in duration or ≥25% of the height of the ensuing R wave or QS pattern in two or more leads;
- right or left bundle branch block with QRS duration ≥0.12 s;
- R or R′ wave in lead V1 ≥ 0.5 mV in amplitude and R/S ratio ≥1.

ST-segment, T-waves, and QT interval
- ST-segment depression or T-wave flattening or inversion in two or more leads;
- prolongation of heart rate corrected QT interval >0.44 s in males and > 0.46 s in females.

Rhythm and conduction abnormalities
- premature ventricular beats or more severe ventricular arrhythmias;
- supraventricular tachycardias, atrial flutter, or atrial fibrillation;
- short PR interval (<0.12 s) with or without 'delta' wave;
- sinus bradycardia with resting heart rate ≤40 beats/min[a];
- first (PR ≥ 0.21 s[b]), second or third degree atrioventricular block.

[a]Increasing less than 100 beats/min during limited exercise test.
[b]Not shortening with hyperventilation or limited exercise test.
Modified from Corrado *et al.*[3]

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Annals of Internal Medicine | ARTICLE

Cardiovascular Screening in College Athletes With and Without Electrocardiography

A Cross-sectional Study

Aaron L. Baggish, MD; Adolph M. Hutter Jr., MD; Francis Wang, MD; Kibar Yared, MD; Rory B. Weiner, MD; Eli Kupperman, BA; Michael H. Picard, MD; and Malissa J. Wood, MD

Conclusion: Adding ECG to medical history and physical examination improves the overall sensitivity of preparticipation cardiovascular screening in athletes. However, this strategy is associated with an increased rate of false-positive results when current ECG interpretation criteria are used.

False Positive Rate of 16.4%

Annals of Internal Medicine 2010;152:269-275

ECG Criteria: An Evolution

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Cost and yield of adding electrocardiography to history and physical in screening Division I intercollegiate athletes: A 5-year experience

Rohit Malhotra, MD,*† J. Jason West, MD,*† John Dent, MD,*† Max Luna, MD,*† Christopher M. Kramer, MD,*† J. Paul Mounsey, BM, BCh, PhD,¶ Robert Battle, MD,*† Ethan Saliba, PhD,‡§‖ Benjamin Rose,§ Dilaawar Mistry, MD,*‡§‖ John MacKnight, MD,*‡§ John. P. DiMarco, MD, PhD, FHRS,* Srijoy Mahapatra, MD, FHRS*†§

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- ~1500 athletes
- H & P + ECG on all
- ECG + in 19%
- Detection of 8 path. conditions
- 395 Additional tests
- Similar cost / finding

Heart Rhythm 2011

Cardiovascular Screening with Electrocardiography and Echocardiography in Collegiate Athletes

Anthony Magalski, MD,[a] Marcia McCoy, RN, MSN,[a] Michael Zabel, MD,[b] Lawrence M. Magee, MD,[c] Joseph Goeke, MD,[a] Michael L. Main, MD,[a] Linda Bunten, RN, BSN,[a] Kimberly J. Reid, MS,[a] Brian M. Ramza, MD, PhD[a]

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- ~1000 athletes
- H & P + ECG + Echo on all
- ECG "distinctly" + in 10%
- Detection of 9 path. conditions
- Blacks and females more ECG+
- Echo not incrementally useful

Am J Med 2011

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An ECG False Positivity Rate of 10-20% !!!

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European Heart Journal (2010) 31, 243–259
doi:10.1093/eurheartj/ehp473

ESC REPORT

Recommendations for interpretation of 12-lead electrocardiogram in the athlete

Domenico Corrado[1]*, Antonio Pelliccia[2], Hein Heidbuchel[3], Sanjay Sharma[4], Mark Link[5], Cristina Basso[6], Alessandro Biffi[2], Gianfranco Buja[1], Pietro Delise[7], Ihor Gussac[8], Aris Anastasakis[9], Mats Borjesson[10], Hans Halvor Bjørnstad[11], François Carrè[12], Asterios Deligiannis[13], Dorian Dugmore[14], Robert Fagard[3], Jan Hoogsteen[15], Klaus P. Mellwig[16], Nicole Panhuyzen-Goedkoop[17], Erik Solberg[18], Luc Vanhees[3], Jonathan Drezner[19], N.A. Mark Estes, III[5], Sabino Iliceto[1], Barry J. Maron[20], Roberto Peidro[21], Peter J. Schwartz[22], Ricardo Stein[23], Gaetano Thiene[6], Paolo Zeppilli[24], and William J. McKenna[25] on behalf of the Sections of Sports Cardiology of the European Association of Cardiovascular Prevention and Rehabilitation; and the Working Group of Myocardial and Pericardial Disease of the European Society of Cardiology

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Received 20 July 2009; revised 22 September 2009; accepted 4 October 2009; online publish-ahead-of-print 20 November 2009

Cardiovascular remodelling in the conditioned athlete is frequently associated with physiological ECG changes. Abnormalities, however, may be detected which represent expression of an underlying heart disease that puts the athlete at risk of arrhythmic cardiac arrest during sports. It is mandatory that ECG changes resulting from intensive physical training are distinguished from abnormalities which reflect a potential cardiac pathology. The present article represents the consensus statement of an international panel of cardiologists and sports medical physicians with expertise in the fields of electrocardiography, imaging, inherited cardiovascular disease, cardiovascular pathology, and management of young competitive athletes. The document provides cardiologists and sports medical physicians with a modern approach to correct interpretation of 12-lead ECG in the athlete and emerging understanding of incomplete penetrance of inherited cardiovascular disease. When the ECG of an athlete is examined, the main objective is to distinguish between physiological patterns that should cause no alarm and those that require action and/or additional testing to exclude (or confirm) the suspicion of an underlying cardiovascular condition carrying the risk of sudden death during sports. The aim of the present position paper is to provide a framework for this distinction. For every ECG abnormality, the document focuses on the ensuing clinical work-up required for differential diagnosis and clinical assessment. When appropriate the referral options for risk stratification and cardiovascular management of the athlete are briefly addressed.

Keywords Athlete's heart • Cardiomyopathy • Electrocardiogram • Ion-channel disease • Sudden death • Ventricular fibrillation • Ventricular tachycardia

Table 1 Classification of abnormalities of the athlete's electrocardiogram

Group 1: common and training-related ECG changes	Group 2: uncommon and training-unrelated ECG changes
Sinus bradycardia	T-wave inversion
First-degree AV block	ST-segment depression
Incomplete RBBB	Pathological Q-waves
Early repolarization	Left atrial enlargement
Isolated QRS voltage criteria for left ventricular hypertrophy	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

RBBB, right bundle branch block; LBBB, left bundle branch block.

ECG Criteria: An Evolution

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Performance of the 2010 European Society of Cardiology criteria for ECG interpretation in the athlete

Rory B Weiner,[1] Adolph M Hutter,[1] Francis Wang,[2] Jonathan H Kim,[1]
Malissa J Wood,[1] Thomas J Wang,[1] Michael H Picard,[1] Aaron L Baggish[1]

2005 Criteria

False Pos. Rate = 16.4%

Screening Strategy	Sensitivity	Specificity	PPV	NPV
MH / PE	45.5 (18.1,75.4)	94.4 (91.9,96.2)	15.0 (5.7,32.7)	98.7 (97.1 , 99.5)
MH/ PE + ECG	90.9 (57.1,99.5)	82.7 (79.0,85.9)	10.4 (5.4,18.7)	99.8 (98.4 , 100.0)

2010 Criteria

False Pos. Rate = 8.6%

Screening Strategy	Sensitivity	Specificity	PPV	NPV
MH / PE	45.5 (18.1,75.4)	94.4 (91.9,96.2)	15.0 (5.7,32.7)	98.7 (97.1 , 99.5)
MH/ PE + ECG	90.9 (57.1,99.5)	91.3 (88.7,95.9)	6.5 (5.4,18.7)	100.0 (100.0 , 100.0)

Weiner et al. Heart 2010

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Original Articles

Early Repolarization Pattern in Comp

Clinical Correlates and the Effects of Exe

Peter A. Noseworthy, MD; Rory Weiner, MD; Jonathan Kim, Francis Wang, MD; Brant Berkstresser, MS, ATC; Mali Thomas J. Wang, MD; Michael H. Picard, MD; Adolph Christopher Newton-Cheh, MD, MPH; Aaron L. B

Background—Inferior lead early repolarization pattern (ERP) recently has been Although ERP is common among athletes, prevalence, ECG lead distribution, physical training remain uncertain. We sought to examine the nonanterior ERP

Methods and Results—ERP was assessed in a cross-sectional cohort of collegia between ERP and cardiac structure were then examined in a longitudinal subgro period of exercise training. ERP was defined as J-point elevation ≥0.1 mV in territory (inferior [II, III, aVF] or lateral territory [I, aVL, V4–V6]). Nonanterior of athletes, including the inferior subtype in 3.8% (33/879). Exercise trainin prevalence of ERP and the inferior subtype, but there were no associations measures of left ventricular remodeling. In a multivariable model, ERP was assoc 5.84; 95% CI, 3.54 to 9.61; $P<0.001$), increased QRS voltage (OR, 2.08; 95% C heart rate (OR, 1.54; 95% CI, 1.26 to 1.87; $P<0.001$).

Conclusions—Nonanterior ERP, including the inferior subtype, is common and h competitive athletes. The finding of increased ERP prevalence after intense association between exercise and ERP. (*Circ Arrhythm Electrophysiol.* 2011;

Key Words: exercise ■ electrocardiography ■ electro

Since its initial description nearly 75 years ago,[1] the early repolarization pattern (ERP) has been considered a normal variant.[2–4] However, emerging evidence from case-control[5,6] and prospective cohort[7] studies suggests that ERP in the inferior leads is associated with an increased risk of sudden cardiac death (SCD). The prevalence, clinical associations, and underlying mechanisms of this potentially malignant ERP subtype remains largely unstudied in young competitive athletes. Although SCD in athletes is relatively rare, it is an important clinical problem with a devastating impact on families and communities. Valuable athlete SCD registry data have shown that the majority of athlete SCD is attributable to cardiac causes but that an identifiable cardiac disorder is absent roughly one third of the time.[8] Mechanisms and markers of electric instability in the absence of identifiable heart disease are lacking in this population.

Clinical Perspective on p 440

It is well established that ERP is more common among young athletes (prevalence estimates of 20% to 90%) than in the general populati and potentially mali oughly examined in available longitudina cise training on ERP study to examine th distribution, clinical ing, and structural hel with ERP and the athletes.

Study Design

We used cross-sectiona to examine specific as cross-sectional cohort was recruited to exam associated with the pre studied in a prospecti effects of exercise train on ERP.

Received February 11, 2011; accepted April 14, 2011.
From the Cardiovascular Research Center, Massachusetts General Hospital, Boston, MA (P.A.N., R.W C.N.-C., A.L.B.); and Harvard University Health Services, Cambridge, MA (A.L.B., P.W., B.B.).
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Circ Arrhythm Electrophysiol is available at http://circep.ahajournals.org

The prevalence, distribution, and clinical outcomes of electrocardiographic repolarization patterns in male athle of African/Afro-Caribbean origin

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Received 7 January 2011; revised 15 February 2011; accepted 25 March 2011; online publish-ahead-of-print 25 May 2011

Aims Athletic training in male black athletes (BAs) is associated with marked ECG repo hypertrophic cardiomyopathy (HCM). Differentiating between the two entities is prevalence of exercise-related sudden death from HCM compared with white a

Methods and results Between 1996 and 2010, 904 BAs underwent serial cardiac evaluations incl Athletes exhibiting T-wave inversions were investigated further for HCM. R WAs, 119 black controls (BCs), and 52 black HCM patients. Athletes were fo T-wave inversions were present in 82.7% HCM patients, 22.8% BAs, 10.1% BC major determinant of T-wave inversions was black ethnicity. T-wave inversions confined to contiguous anterior leads (V1–V4). Only 4.1% of BAs exhibited T-wa contrast, both BCs and HCM patients exhibited lower prevalence of T-wave inver respectively) with most T-wave inversions in HCM patients (76.9%) involving the BA survived cardiac arrest and two athletes (one BA, one WA) were diagnose wave inversions in the lateral leads.

Conclusions T-wave inversions in leads V1–V4 appear to represent an ethnic variant of 'athlet sions in the lateral leads may represent the initial expression of underlying cardi ation and regular surveillance.

Keywords Athlete's heart • Echocardiography • Electrocardiography • Ethnicity • Hy

Introduction

Participation in regular, intensive exercise is associated with repolarization changes affecting the ST-segment and T-wave morphology.[1,2] Certain electrical anomalies occasionally overlap with those observed in cardiomyopathies.[3,4] Data from Caucasian athletes [white athletes (WAs)] suggest that 3–4% of athletes exhibit T-wave inversions but their precise significance remains controversial.[1,2,5] Whereas, so sions to represent physiolog study reported sudden cardiac thy in a small proportion of athl changes.[6]

Limited studies in American of African/Afro-Caribbean ori greater prevalence of T-wav

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Significance of Electrocardiographic Right Bundle Branch Block in Trained Athletes

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We sought to determine the clinical and physiologic significance of electrocardiographic complete right bundle branch block (CRBBB) and incomplete right bundle branch block (IRBBB) in trained athletes. The 12-lead electrocardiographic and echocardiographic data from 510 competitive athletes were analyzed. Compared to the 51 age-, sport type-, and gender-matched athletes with normal 12-lead electrocardiographic QRS complex duration, the 44 athletes with IRBBB (9%) and 13 with CRBBB (3%) had larger right ventricular (RV) dimensions, as measured by the basal RV end-diastolic diameter (CRBBB 43 ± 3 mm, IRBBB 38 ± 6 mm, normal QRS complex 35 ± 4 mm, p <0.001) and RV end-diastolic area (CRBBB 33 ± 5, IRBBB 27 ± 7, and normal QRS complex 23 ± 3 cm^2; p <0.001). Athletes with CRBBB also had a relative reduction in the RV systolic function at rest as assessed by the RV fractional area change and peak systolic tissue velocity. Finally, QRS prolongation was associated with parallel increases in interventricular dyssynchrony (basal RV to basal lateral left ventricular peak systolic tissue velocity time difference: CRBBB 112 ± 15, IRBBB 73 ± 33, normal QRS complex 43 ± 39 ms, p <0.001). Despite these findings, no athlete with CRBBB or IRBBB was found to have pathologic structural cardiac disease. In conclusion, among trained athletes, CRBBB and IRBBB appear to be markers of a structural and physiological cardiac remodeling triad characterized by RV dilation, a relative reduction in the RV systolic function at rest, and interventricular dyssynchrony. (Am J Cardiol 2011;107:1083–1089)

At present, sparse data are available characterizing the disease prevalence, cardiac structure, and cardiac function in athletic patients with complete right bundle branch block (CRBBB) and incomplete right bundle branch block (IRBBB). We, therefore, conducted the present study with the following objectives. First, we determined the prevalence of CRBBB and IRBBB and their relations to underlying cardiac disease in a large cohort of collegiate athletes. Second, we compared the cardiac structure and function, including mechanical interventricular synchrony, among disease-free athletes with CRBBB, IRBBB, and normal 12-lead electrocardiographic QRS complex duration.

Methods

The present study population included United States university athletes previously enrolled to examine preparticipation cardiovascular disease screening.[5] In brief, newly matriculated university athletes ≥18 years of age underwent a noninvestigational focused medical history and physical examination in accordance with the current American College of Cardiology/American Heart Association guidelines.[7] Each participant provided a designation of primary ethnicity and underwent electrocardiography and transthoracic echocardiography at enrollment, as detailed in the following paragraphs. The training volume (hours/week) and training type (endurance vs strength) during the 8 weeks before enrollment was assessed for each participant. Prestudy period endurance activity was defined as running, cycling, swimming, rowing, or aerobic machine use at an effort sustainable for ≥20 minutes, and strength activity was defined as weight lifting, plyometric exercise, and sprint running drills. All participants had provided written consent before enrollment, and the Partners Human Research Committee had approved all aspects of the present study.

The echocardiographic and electrocardiographic (ECG) data were used to identify those with suspected underlying cardiac pathologic findings relevant to sport participation, as outlined in the Thirty-Sixth Bethesda Conference criteria and recent European Society of Cardiology guidelines.[8,9] Those participants with suspected pathologic features underwent individualized, noninvestigational evaluation at the discretion of their physicians to confirm or exclude true cardiac disease. The prevalence of CRBBB and IRBBB and their relations to the underlying cardiac pathologic features were determined in the overall cohort.

A nested case-control approach was then used to compare the myocardial structure and function among disease-free participants with CRBBB, IRBBB, and normal QRS complex duration. Specifically, each participant with either CRBBB or IRBBB and with technically adequate echocardiographic images for complete assessment was matched to a participant with normal QRS complex duration of a sim-

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0002-9149/11/$ – see front matter © 2011 Elsevier Inc. All rights reserved.
doi:10.1016/j.amjcard.2010.11.037

ECG Criteria: An Evolution

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Normal electrocardiographic findings: recognising physiological adaptations in athletes

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This document was developed in collaboration between the American Medical Society for Sports Medicine (AMSSM), the Section on Sports Cardiology of the European Association for Cardiovascular Prevention and Rehabilitation (EACPR), a registered branch of the European Society of Cardiology (ESC), the FIFA Medical Assessment and Research Center (F-MARC), and the Pediatric & Congenital Electrophysiology Society (PACES).

ABSTRACT

Electrocardiographic changes in athletes are common and usually reflect benign structural and electrical remodelling of the heart as a physiological adaptation to regular and sustained physical training (athlete's heart). The ability to identify an abnormality on the 12-lead ECG, suggestive of underlying cardiac disease associated with sudden cardiac death (SCD), is based on a sound working knowledge of the normal ECG characteristics within the athletic population. This document will assist physicians in identifying normal ECG patterns commonly found in athletes. The ECG findings presented as normal in athletes were established by an international consensus panel of experts in sports cardiology and sports medicine.

INTRODUCTION

Sudden death from intrinsic cardiac conditions remains the leading cause of mortality in athletes during sport.[1 2] A resting 12-lead ECG is utilised as a diagnostic tool in the evaluation of both symptomatic and asymptomatic athletes for conditions associated with sudden cardiac death (SCD). The purpose of pre-participation cardiovascular screening is to provide medical clearance for participation in sport through routine systematic evaluations intended to identify pre-existing cardiovascular abnormalities, and thereby reduce the potential for adverse cardiac events and loss of life.[3] Many pre-participation screening programmes include an ECG. Physicians responsible for the cardiovascular care of athletes should be knowledgeable of the physiological cardiac adaptations to regular exercise that are manifested on the ECG.

ECG changes in athletes are common and usually reflect the electrical and structural remodelling or autonomic nervous system adaptations that occur as a consequence of regular and sustained physical activity (ie, athlete's heart). In fact, up to 60% of athletes demonstrate ECG changes (in isolation or in combination) such as sinus bradycardia, sinus arrhythmia, first-degree atrioventricular (AV) block, early repolarisation, incomplete right bundle branch block (IRBBB) and voltage criteria for left ventricular hypertrophy (LVH).[4] The extent of these changes is also dependent on the athlete's ethnicity, age, gender, sporting discipline and level of training and competition.[5–7] Accordingly, the ability to identify an abnormal ECG suggestive of underlying cardiac disease is based on a sound understanding of ECG normality within a broad spectrum of athletic populations.

Concerns for the physician when interpreting an athlete's ECG include both missing a dangerous cardiac condition and generating false-positive interpretations that cause needless further investigations, increased economic cost and potentially unnecessary activity restriction for the athlete.[8] This paper focuses on the physiological ECG adaptations commonly found in athletes to help physicians distinguish normal ECG changes from abnormal ECG findings related to a pathological cardiac condition associated with SCD. Abnormal ECG findings in athletes suggestive of underlying cardiac disease are presented separately.[9 10]

OVERVIEW OF ATHLETE'S HEART

Regular and long-term participation in intensive exercise (minimum of 4 h/week) is associated with unique electrical manifestations that reflect increased vagal tone and enlarged cardiac chamber size. These ECG findings in athletes are considered normal, physiological adaptations to regular exercise and do not require further evaluation (box 1).

Increased vagal tone

Common consequences of increased vagal tone include sinus bradycardia, sinus arrhythmia and early repolarisation (figure 1). Other, less common markers of increased vagal tone are first-degree AV block and Mobitz type I second-degree AV block.

Sinus bradycardia is defined as a heart rate of <60 beats/min and is present in up to 80% of highly trained athletes.[4 11] Heart rates ≥30 beats/min are considered normal in highly trained athletes. Sinus arrhythmia is also common, particularly in younger athletes.

Box 1 Normal ECG findings in athletes

1. Sinus bradycardia (≥30 bpm)
2. Sinus arrhythmia
3. Ectopic atrial rhythm
4. Junctional escape rhythm
5. First-degree AV block (PR interval>200 ms)
6. Mobitz type I (Wenckebach) second-degree 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.

These common training-related ECG alterations are physiological adaptations to regular exercise, considered normal variants in athletes, and do not require further evaluation in asymptomatic athletes.

AV, atrioventricular; bpm, beats per minute; LVH, left ventricular hypertrophy; RBBB, right bundle branch block.

ECG Criteria: An Evolution

Cardiovascular Performance Program

Some overview thoughts about the ECG…

1.) It is an imperfect tool even in the best of hands...

2.) Competence requires criteria familiarity & practice...

3.) It is only one component of patient evalulation....

An ECG in the wrong hands can be a dangerous thing!

Cardiovascular Performance Program

Now, let's put what we've learned about ECG interpretation in athletes to use…..

ECG Interpretation: *Read with the Experts*

Aaron L. Baggish MD

Cardiovascular Performance Program
Division of Cardiology
Massachusetts General Hospital
Boston, MA

MASSACHUSETTS GENERAL HOSPITAL
HEART CENTER

MGH 1811 Cardiovascular Performance Program

Conflicts: None

Athletic Affiliations:

Funding Sources:

- National Institutes of Health
- American Heart Association
- American Society of Echocardiography
- Department of Defense
- National Football League Player's Association

A Teaching Affiliate of Harvard Medical School

Our Task:

- 20 ECGs to review

- Included on each ECG:
  - -Machine generated HR, intervals, & axes
  - -Athlete age, ethnicity, gender, and sport

- Not included with each ECG:
  - -Medical history, physical exam data

- We will assume these are all “asymptomatic” people encountered in a screening setting.

- Our goal, “Is tracing within excepted normal ‘limits’ for a youthful athletic population.

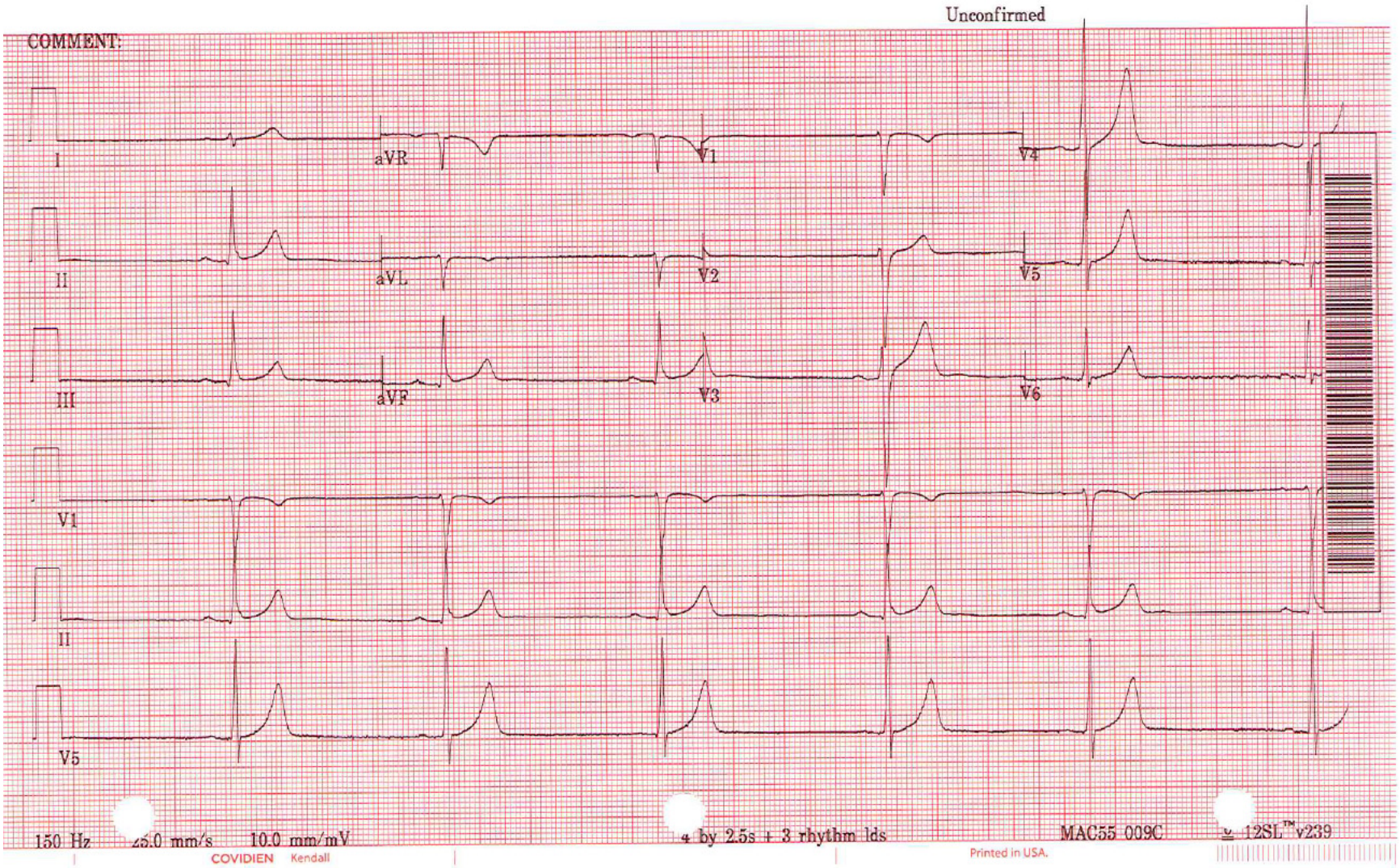
-2 rounds, one with ARS input, “clear” or “not clear”, one with discussion

AMERICAN COLLEGE *of* CARDIOLOGY

ECG#1

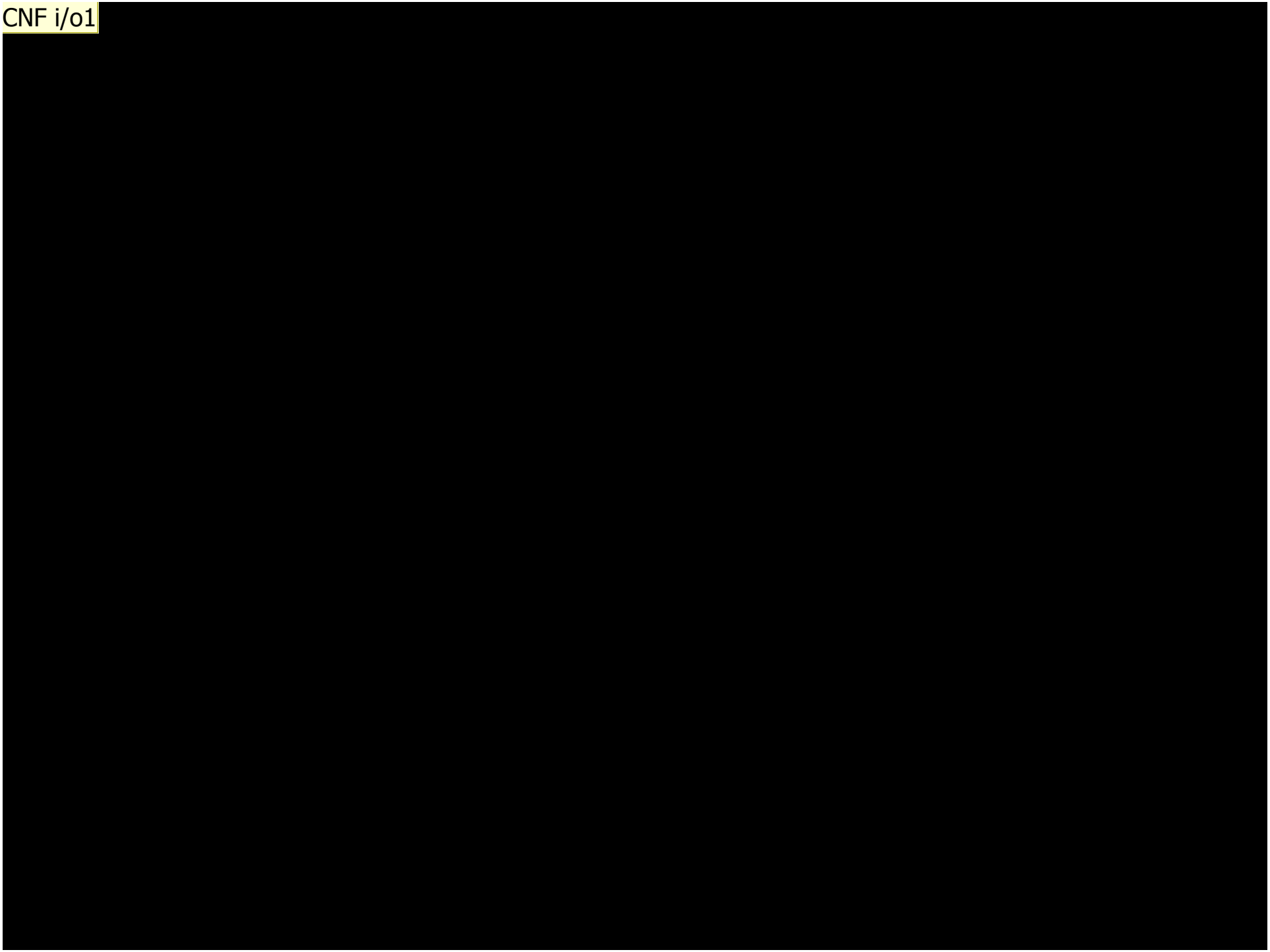
Vent. rate	36 bpm
PR interval	194 ms
QRS duration	118 ms
QT/QTc	492/380 ms
P-R-T axes	68 89 72

22 y.o. White Male Distance Runner



ARS ECG #1:

Clear or Evaluate Further?


CNF i/o1

CNF i/o1 Poll: What would you do?
CNF i/o, 6/16/2016

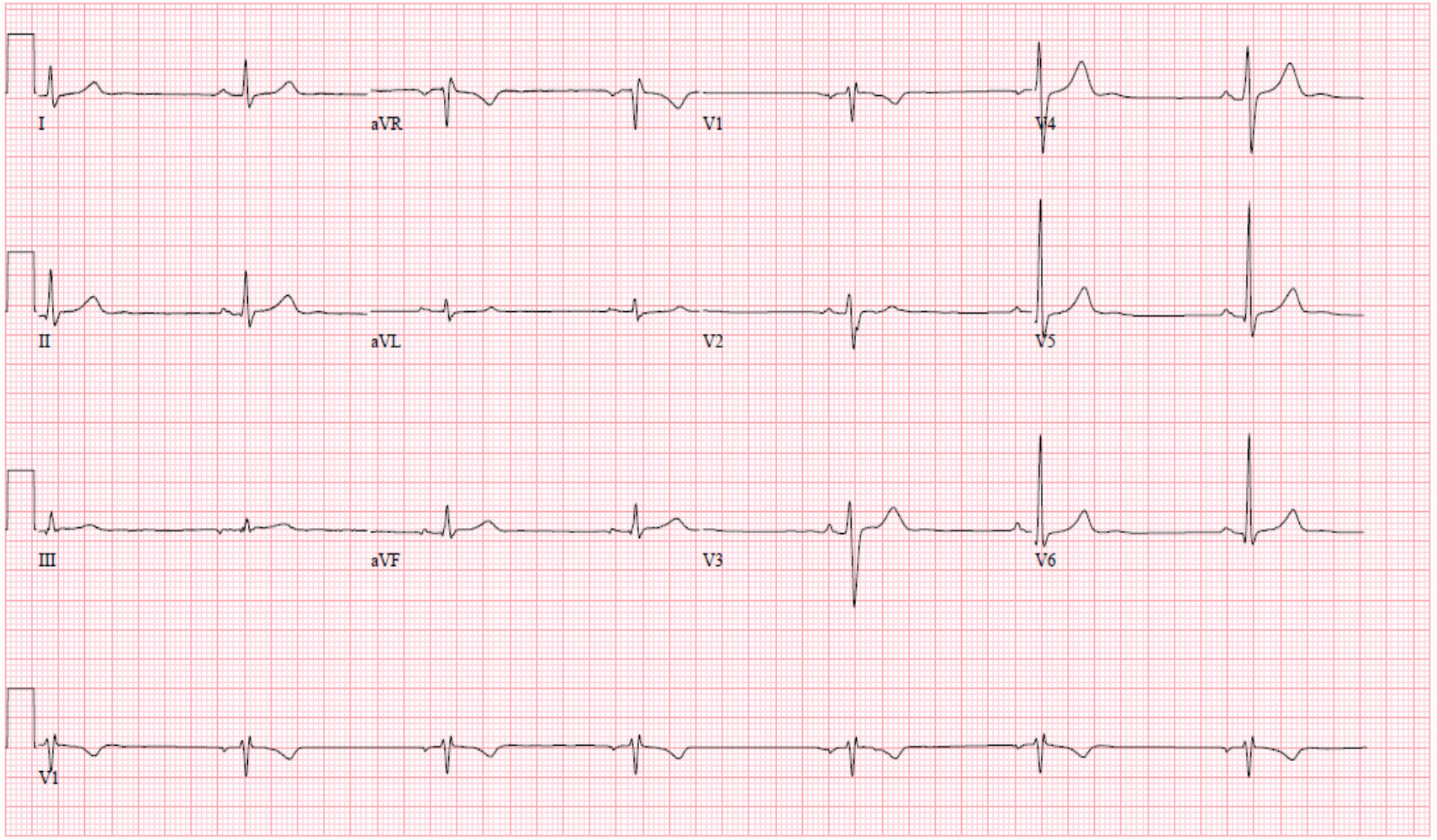
ECG#2

26 y.o. White Female Triathlete

Vent. rate	40
PR interval	170
QRS duration	114
QT/QTc	486/396
P-R-T axes	26 52

Referred by: 031680

Electronically Signed By: AARON L. BAGGISH, M.D.



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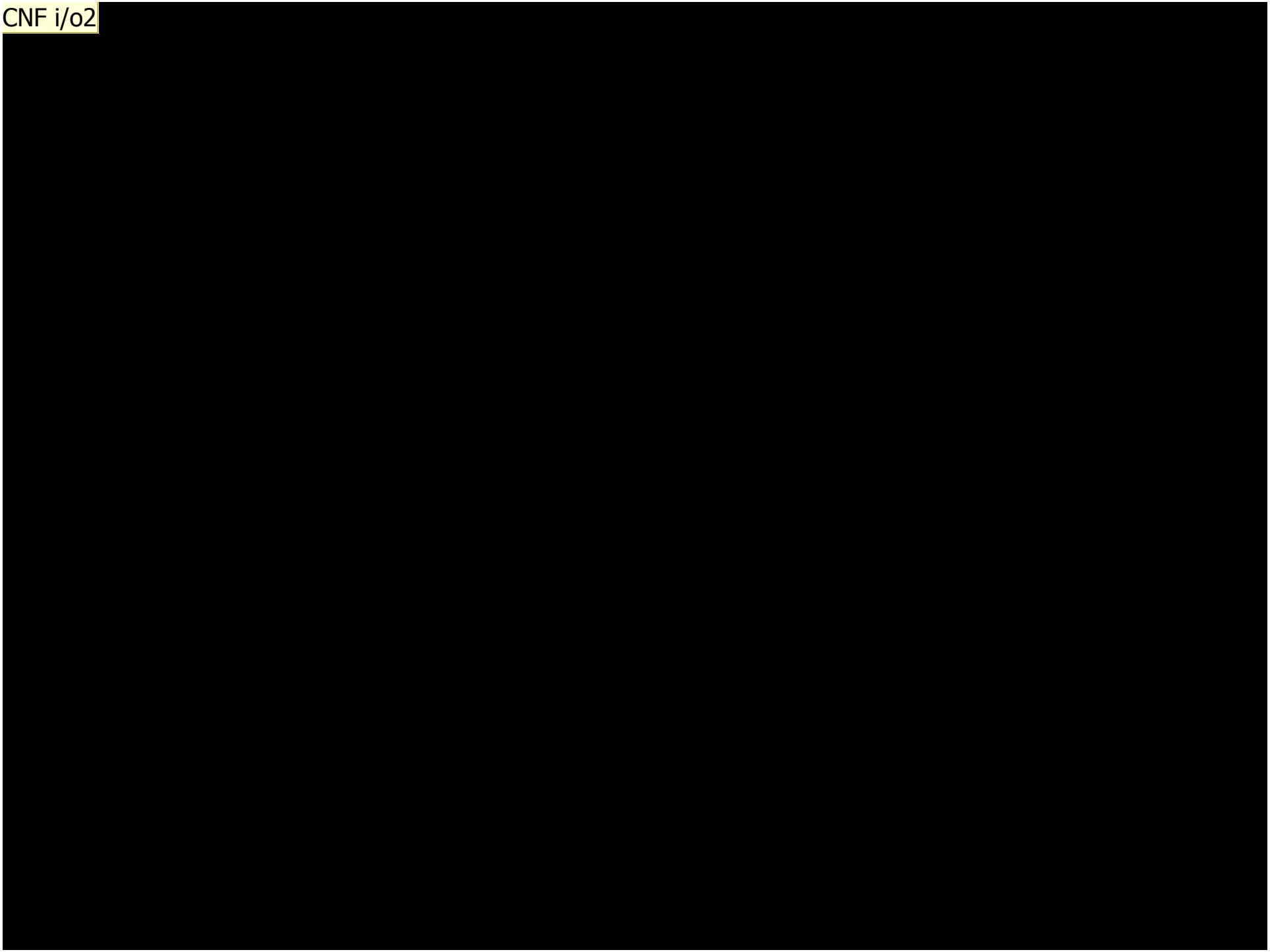
EID:1470 EDT: 10:00 31-JUL-2015 ORDER:

ARS ECG #2:

Clear or Evaluate Further?

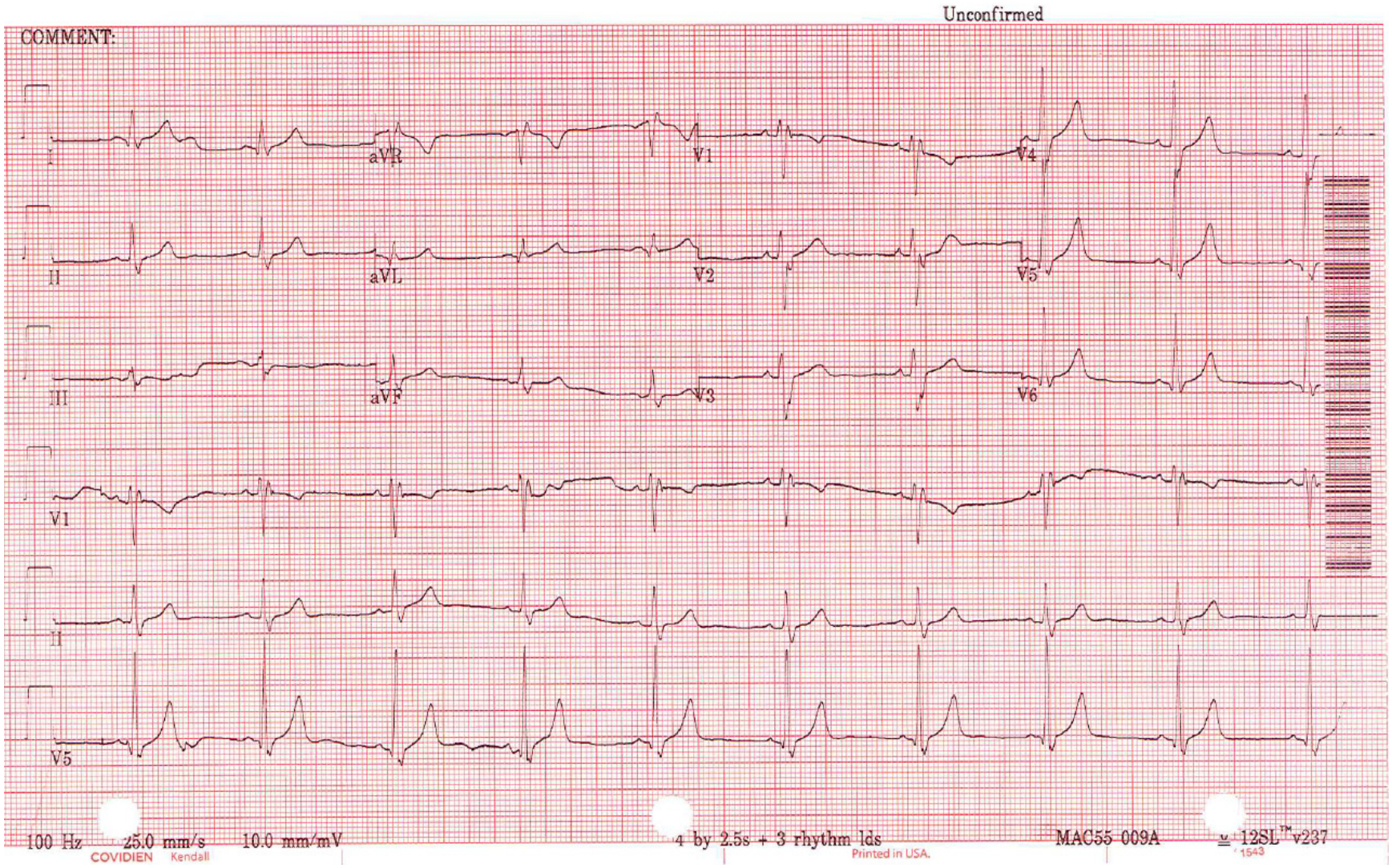

CNF i/o2

CNF i/o2 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#3

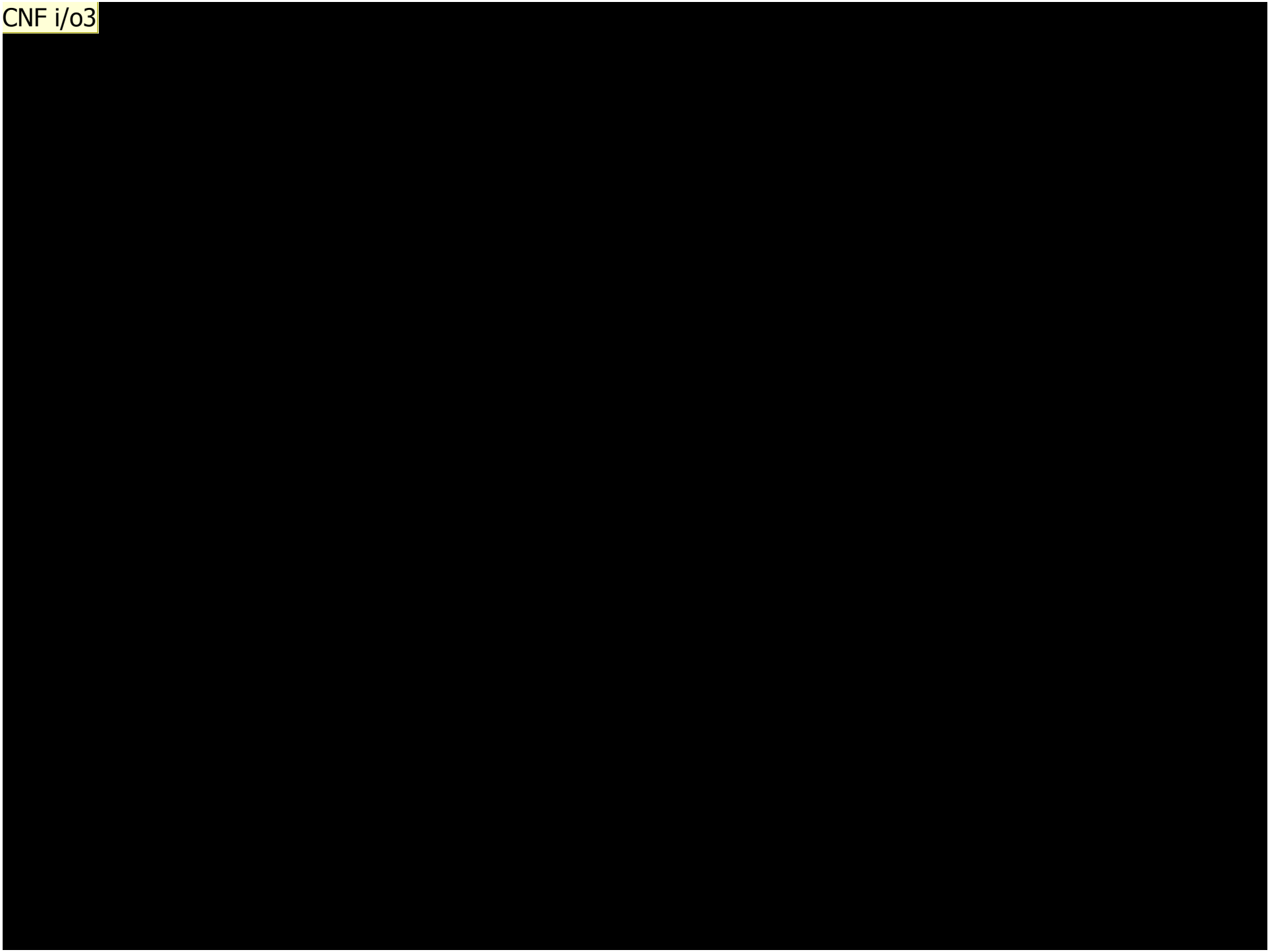
Vent. rate	59 bpm
PR interval	120 ms
QRS duration	118 ms
QT/QTc	412/407 ms
P-R-T axes	28 33 27

18 y.o. Black Male Lacrosse Player



ARS ECG #3:

Clear or Evaluate Further?

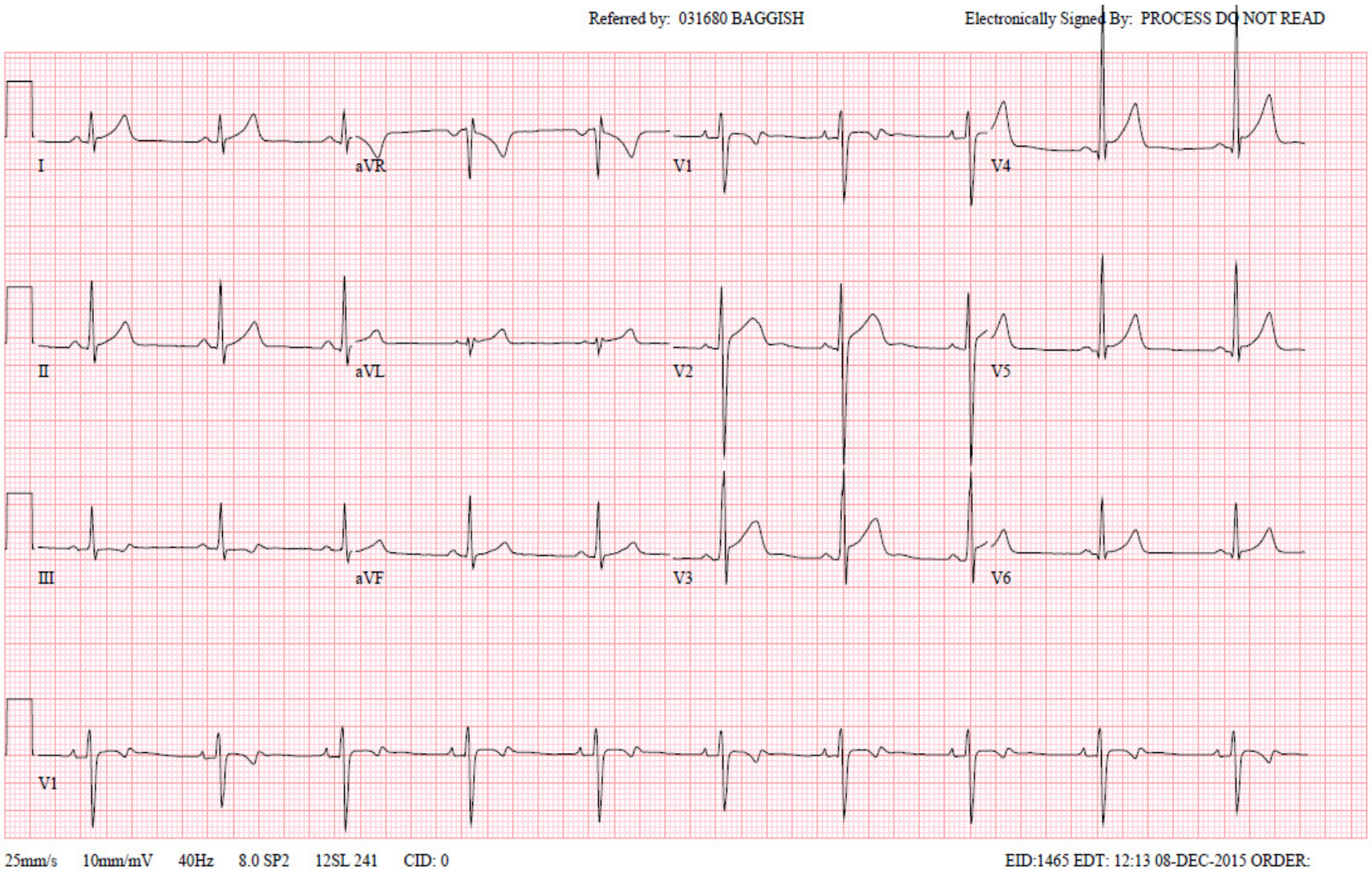

CNF i/o3

CNF i/o3 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#4

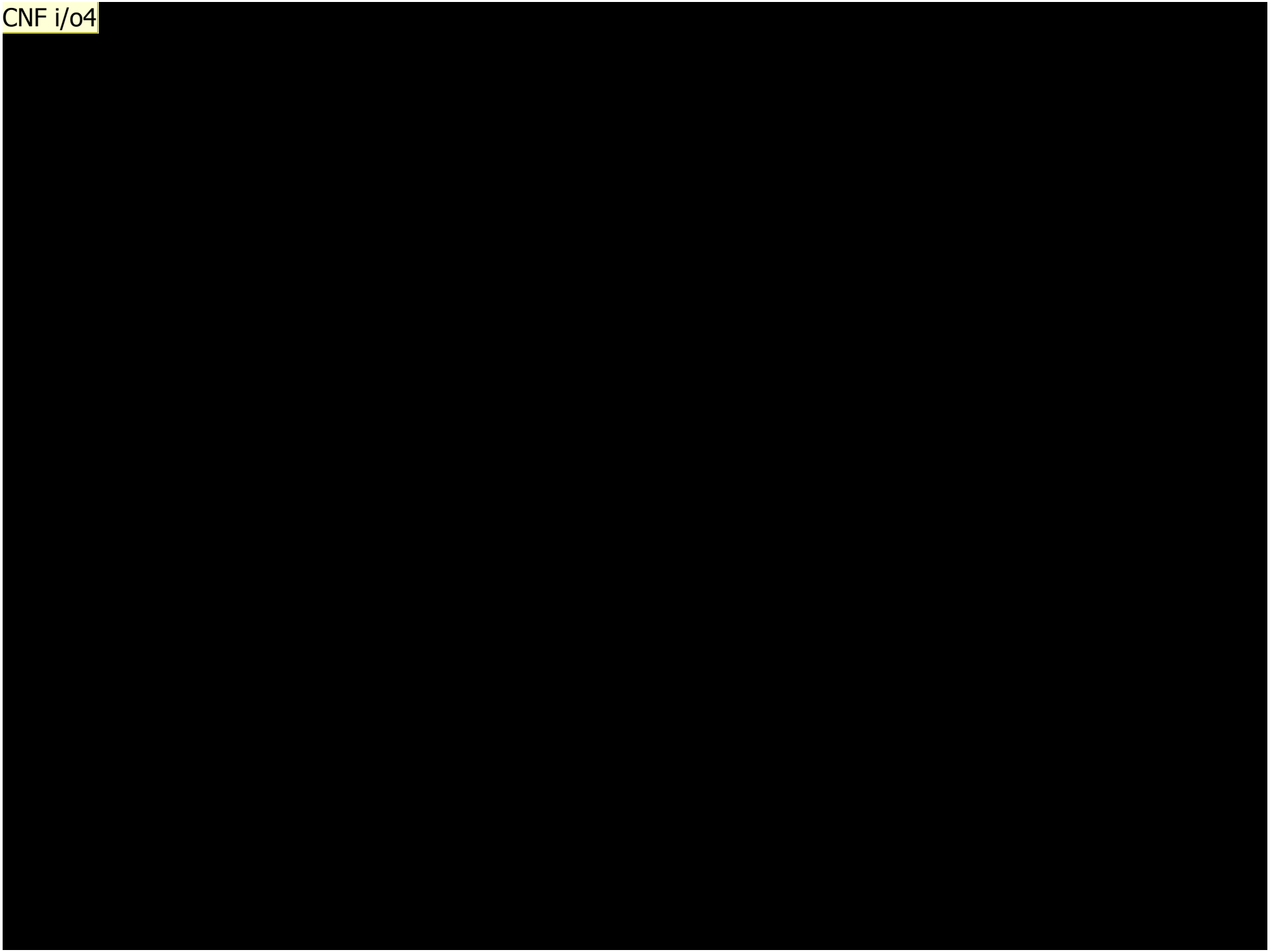
Vent. rate
PR interval
QRS duration
QT/QTc
P-R-T axes

26 y.o. White Male Hockey Player



ARS ECG #4:

Clear or Evaluate Further?

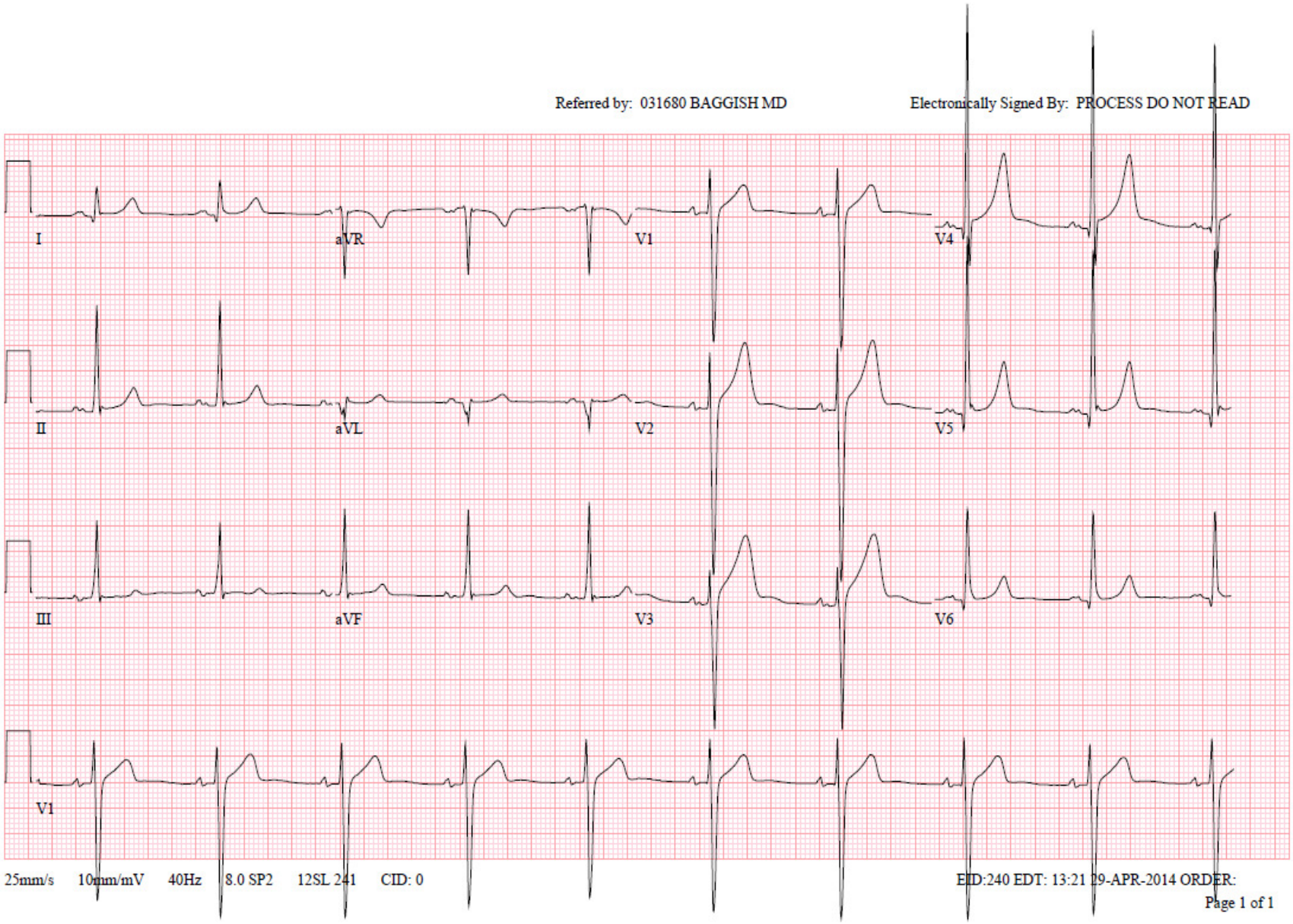

CNF i/o4

CNF i/o4 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#5

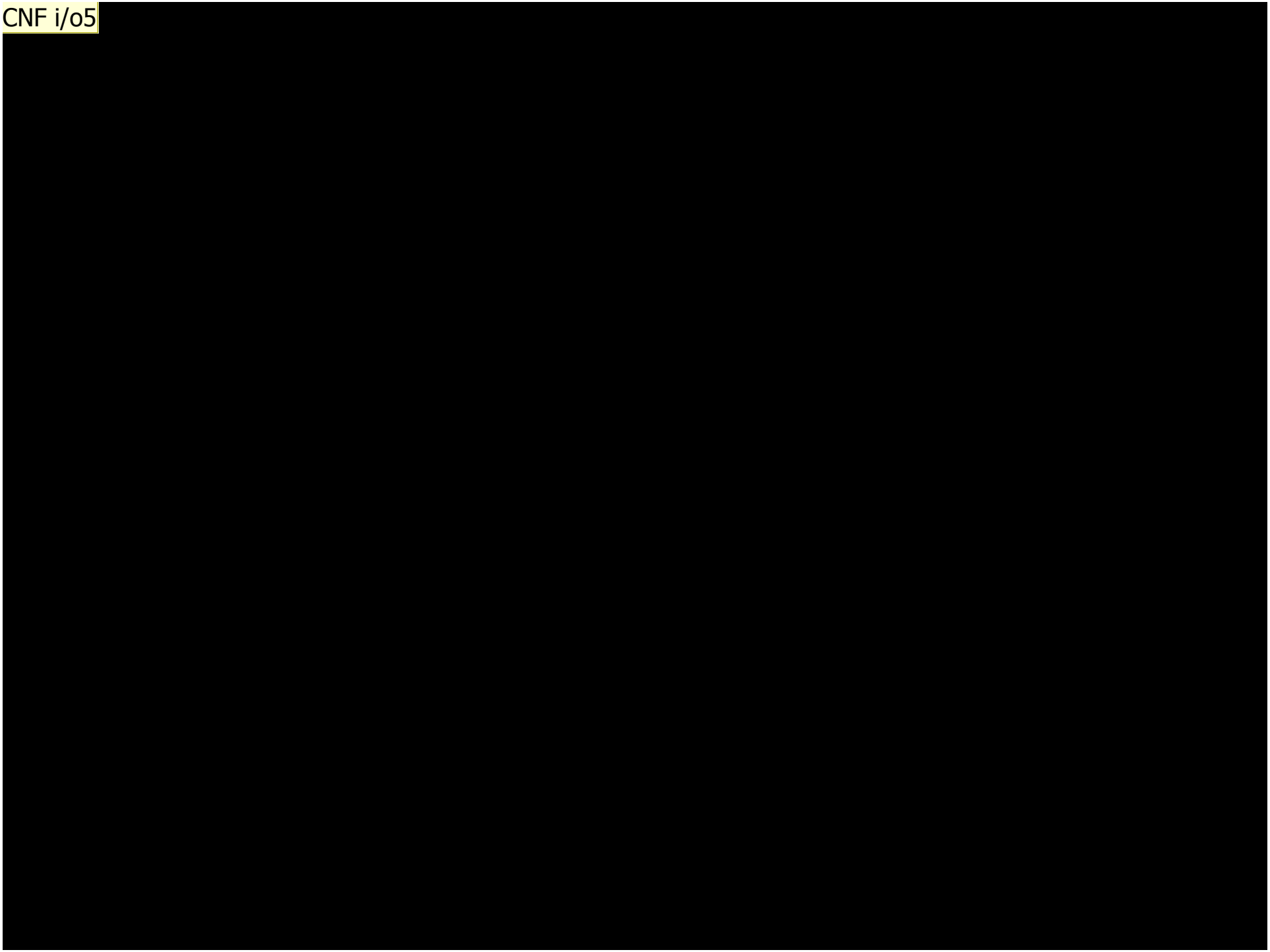
Vent. rate	58	BPM
PR interval	158	ms
QRS duration	104	ms
QT/QTc	442/433	ms
P-R-T axes	30 74	37

19 y.o. White Male Rower



ARS ECG #5:

Clear or Evaluate Further?


CNF i/o5

CNF i/o5 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#6

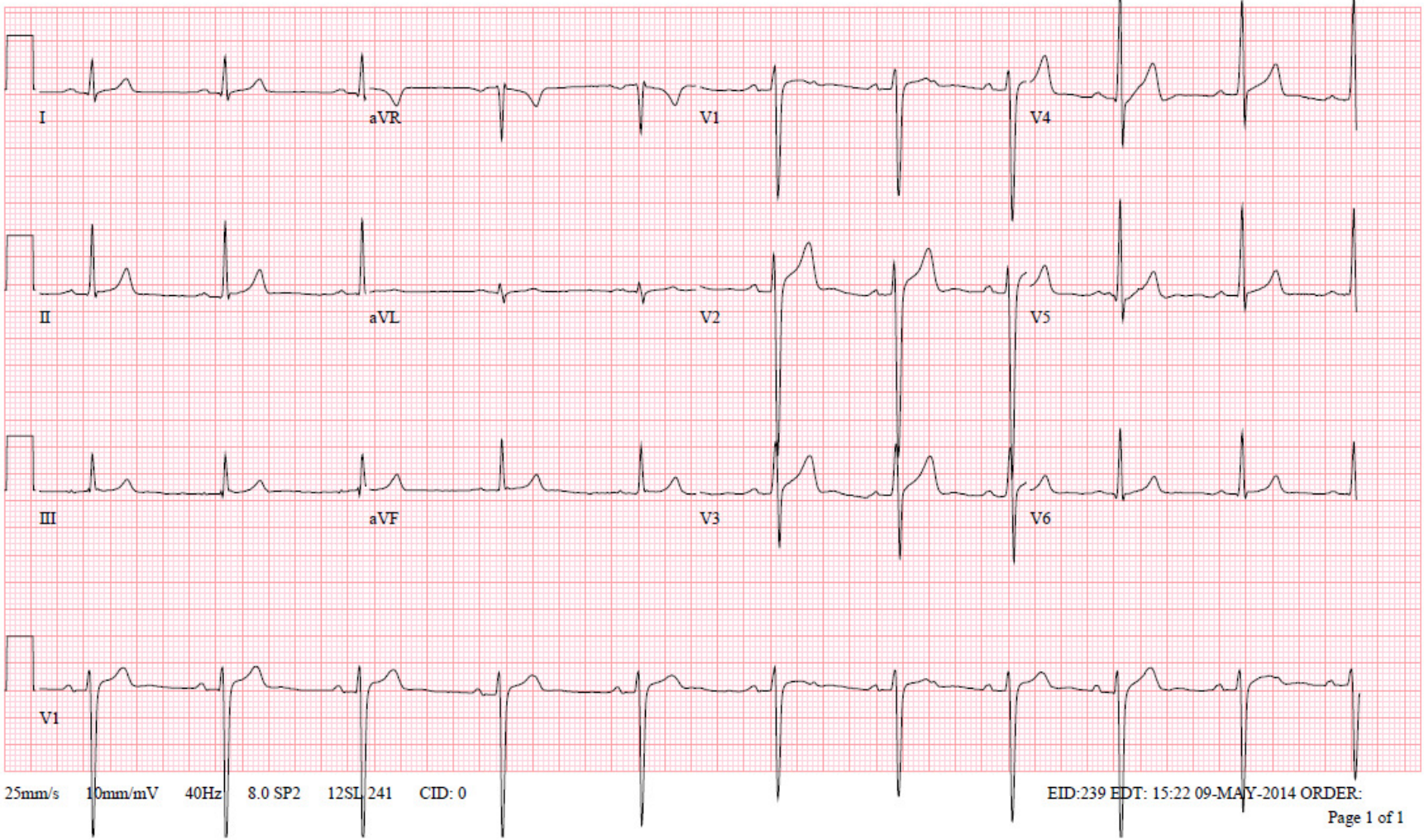
18 y.o. White Male Hurdeler

ID:005413558

Vent. rate	62	BPM
PR interval	174	ms
QRS duration	102	ms
QT/QTc	382/387	ms
P-R-T axes	30 67	51

Referred by: 031680 BAGGISH MD

Electronically Signed By: PROCESS DO NOT READ



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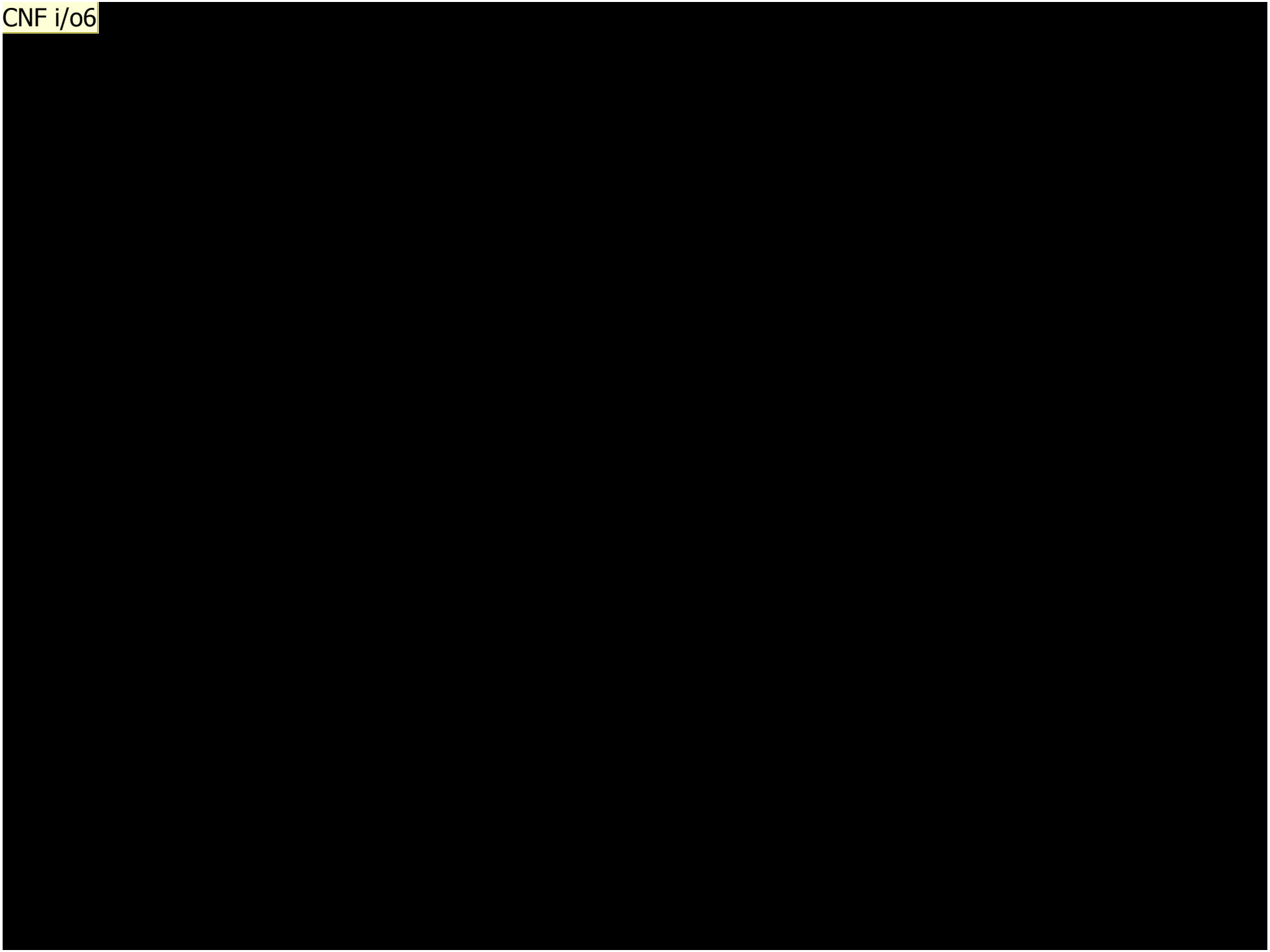
EID:239 EDT: 15:22 09-MAY-2014 ORDER:

ARS ECG #6:

Clear or Evaluate Further?

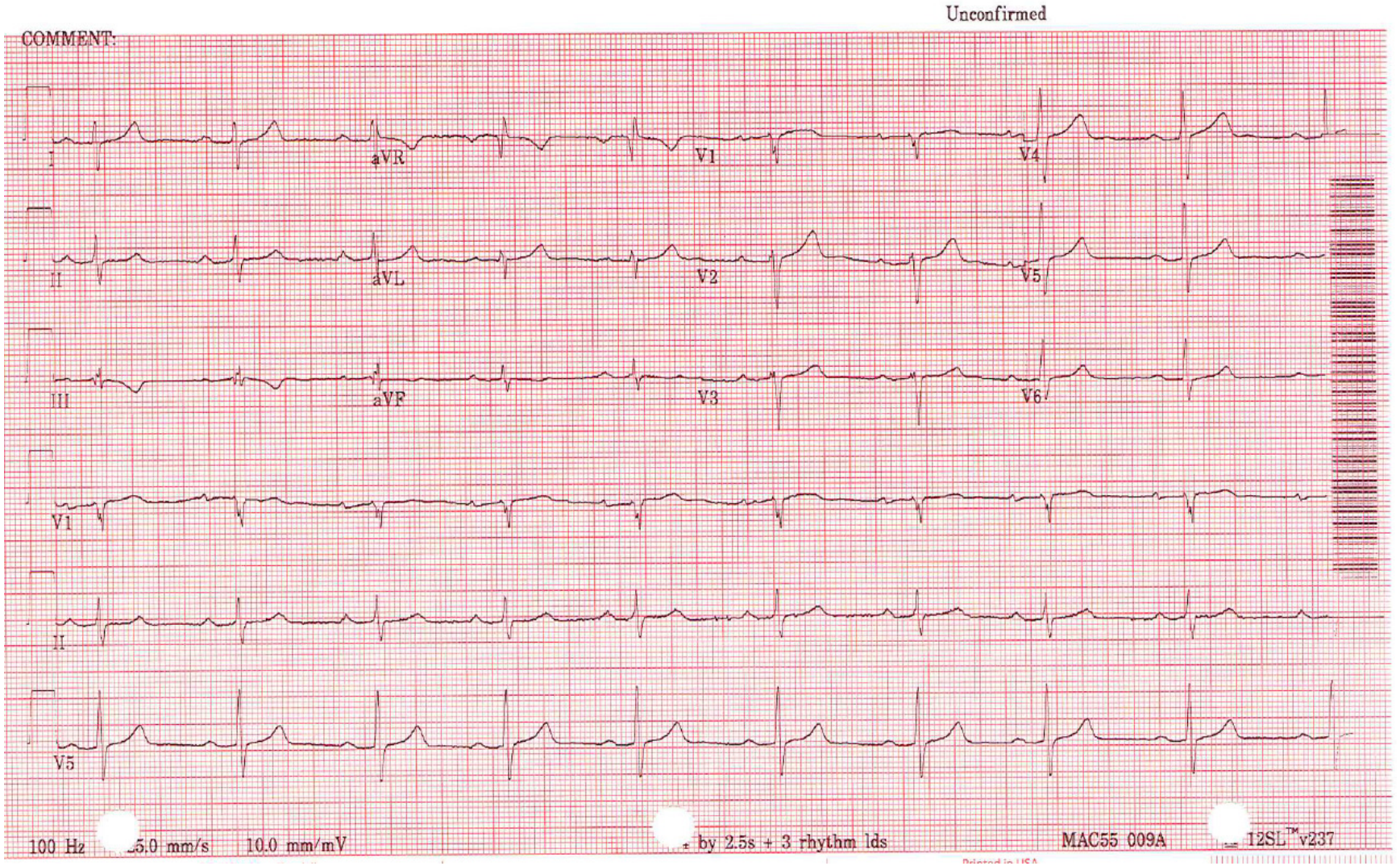

CNF i/o6

CNF i/o6 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#7

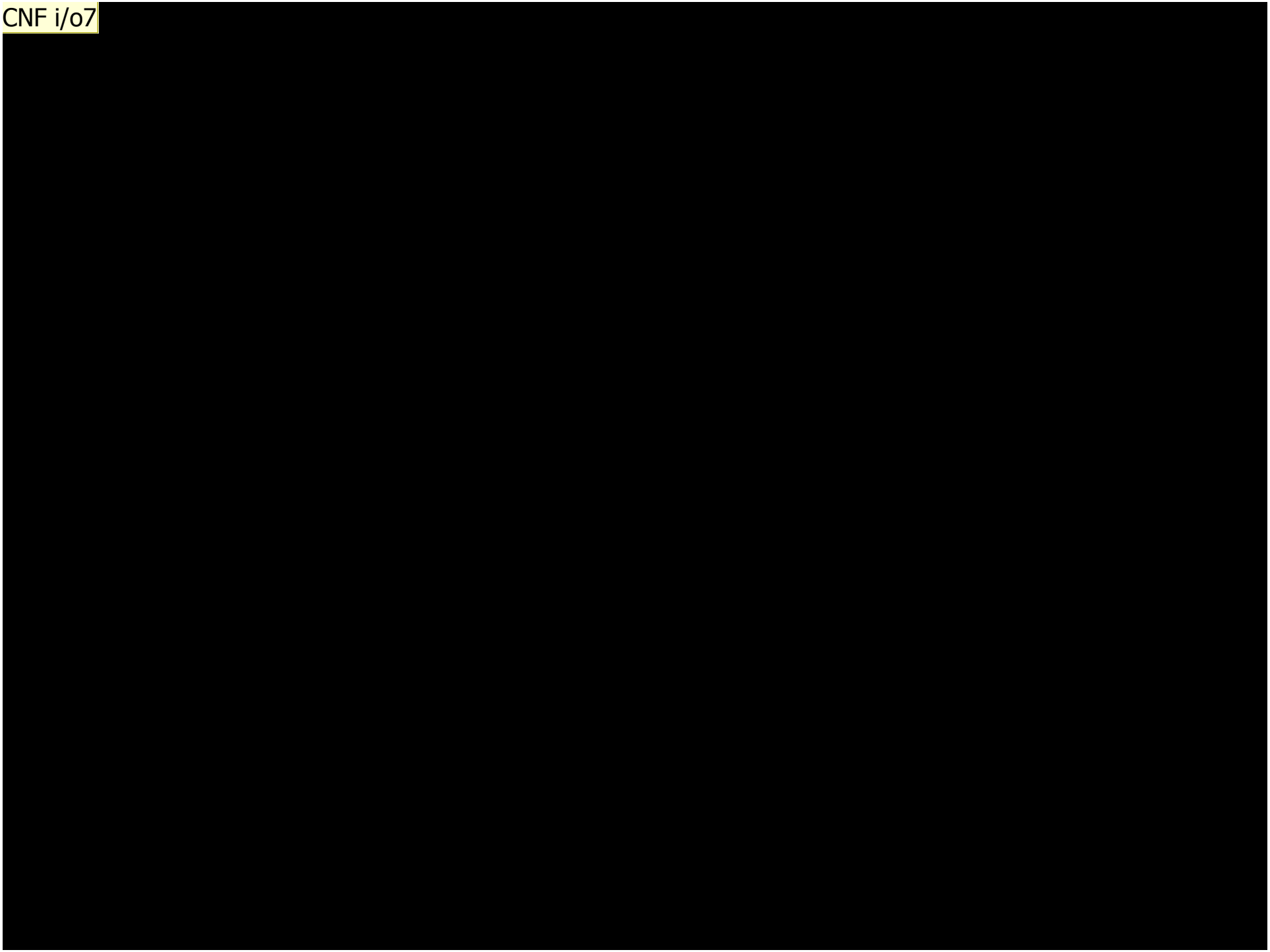
Vent. rate	57 bpm
PR interval	244 ms
QRS duration	102 ms
QT/QTc	446/434 ms
P-R-T axes	36 117 -6

31 y.o. White Male Marathoner



ARS ECG #7:

Clear or Evaluate Further?


CNF i/o7

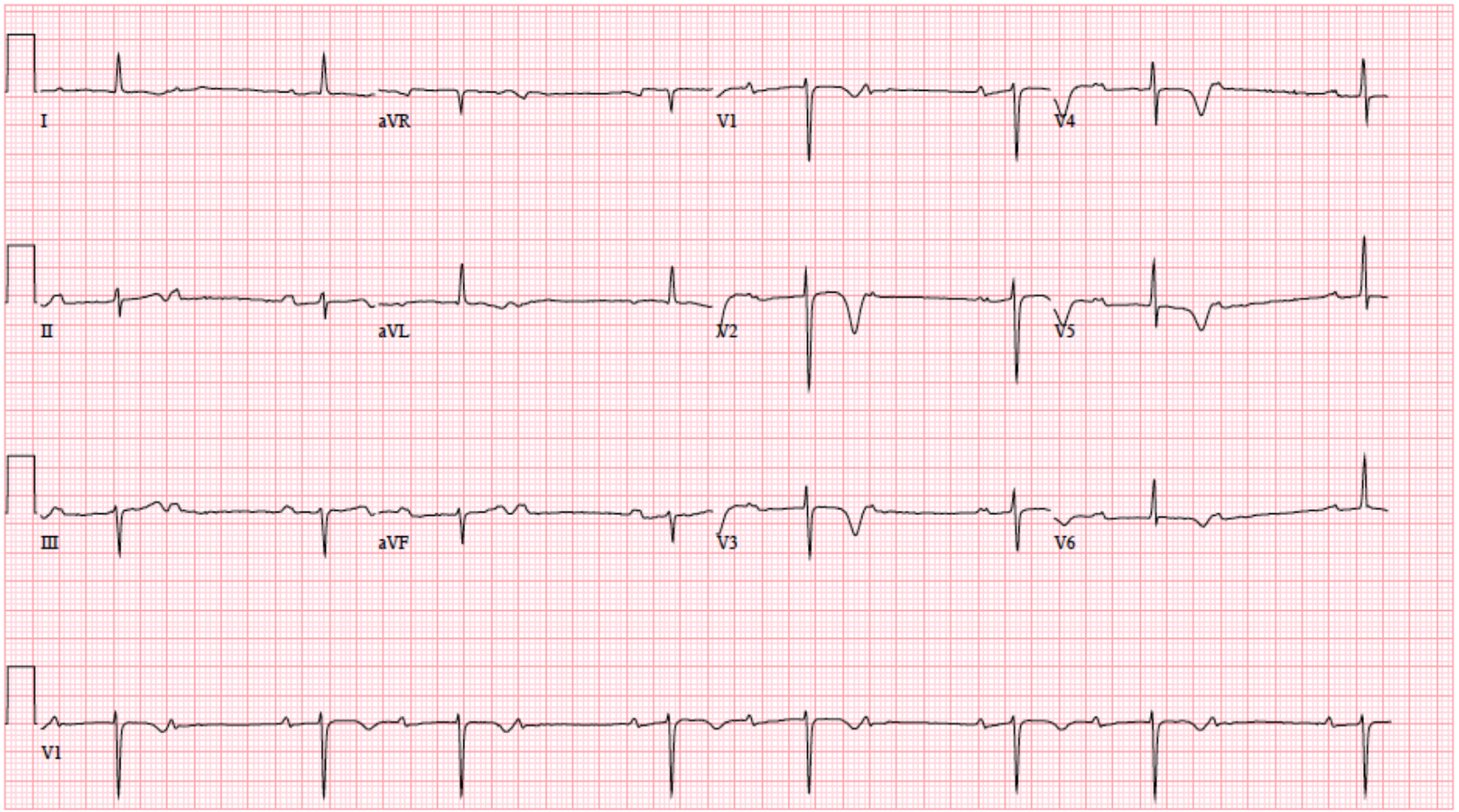
CNF i/o7 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#8

ID:002087600

Vent. rate	45	BPM
PR interval	*	ms
QRS duration	80	ms
QT/QTc	480/415	ms
P-R-T axes	74 -37	117

21 y.o. Black Male Soccer Player



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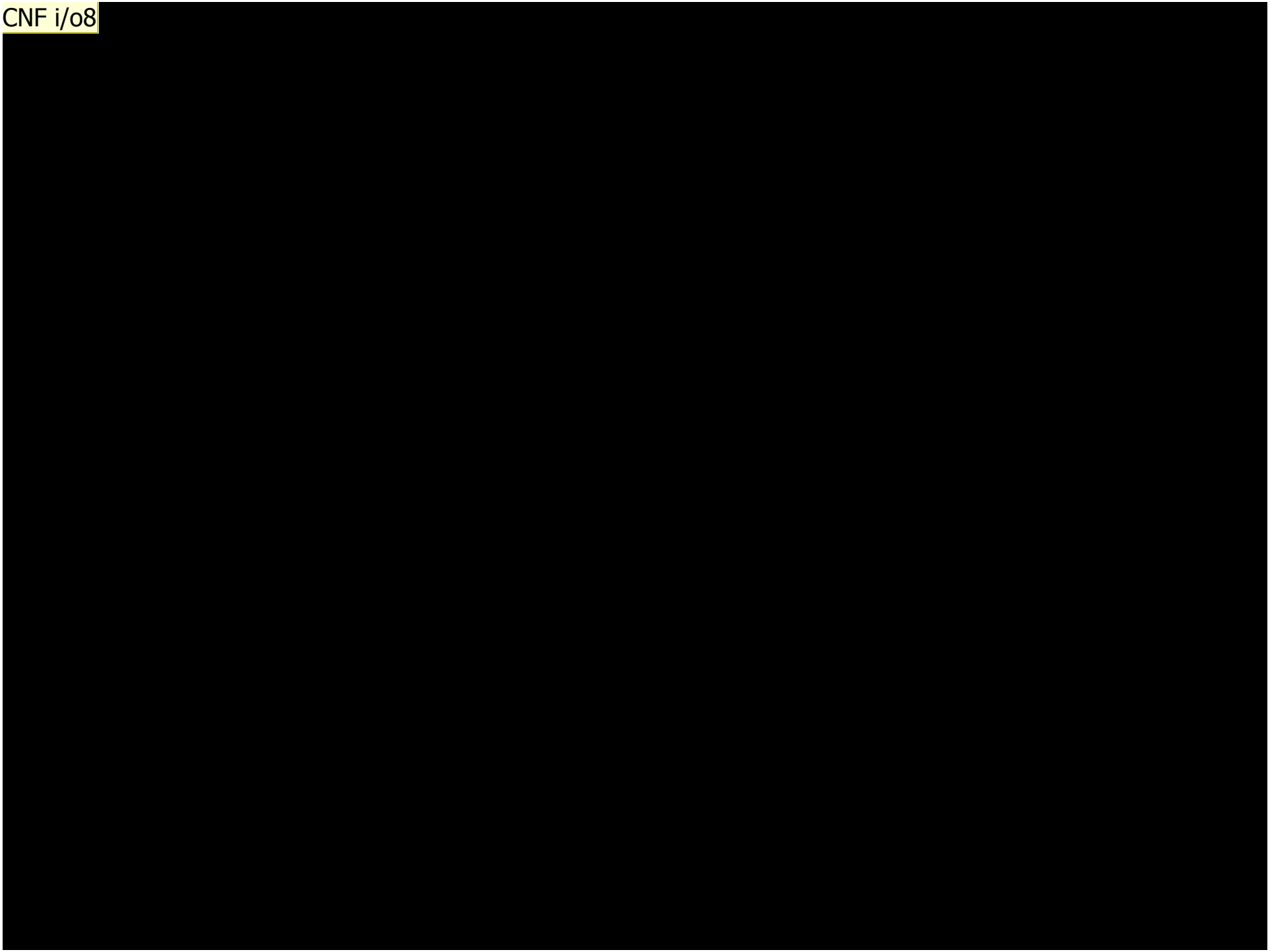
ARS ECG #8:

Clear or Evaluate Further?

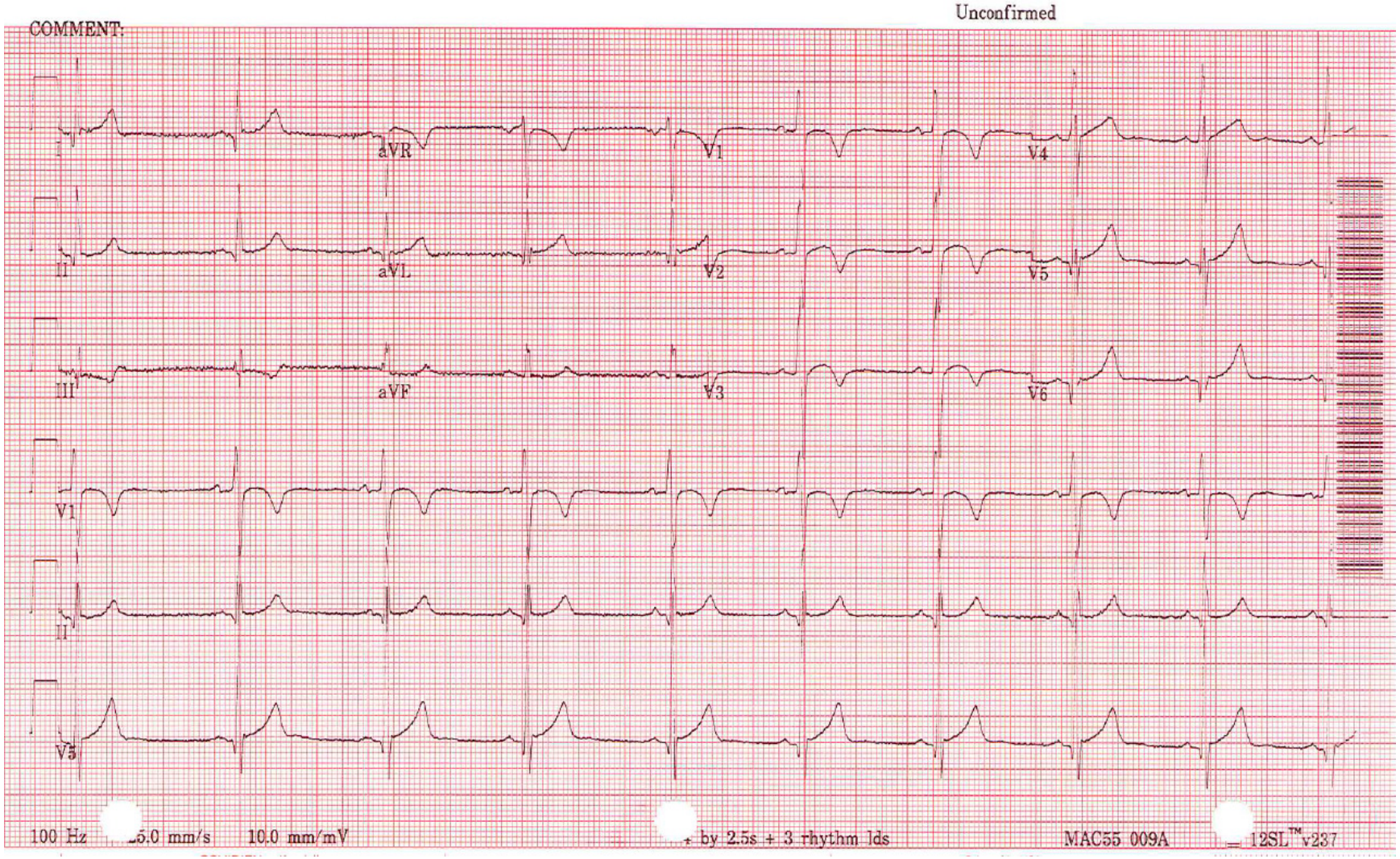

CNF i/o8

CNF i/o8 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#9

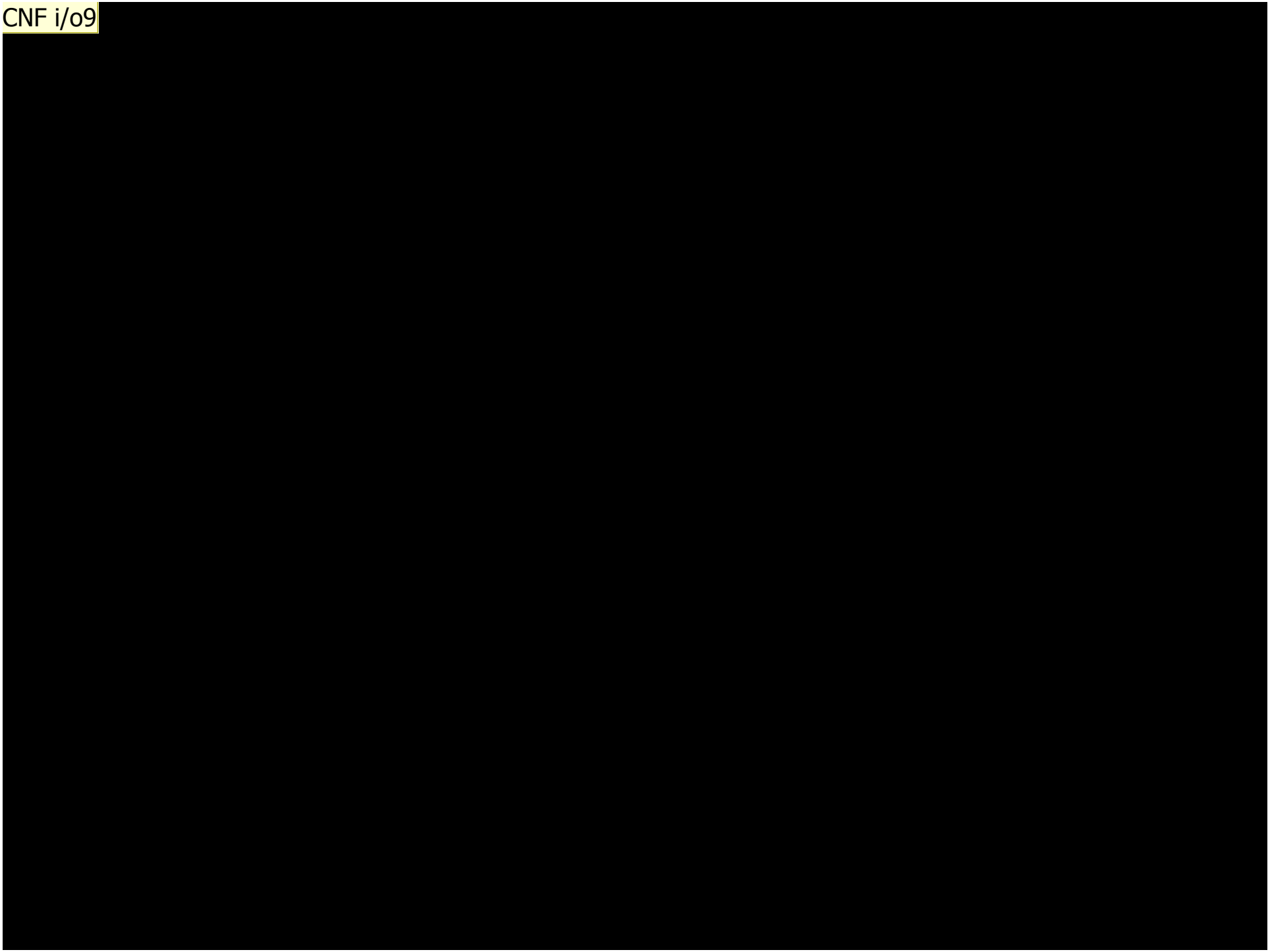
Vent. rate	56 bpm
PR interval	144 ms
QRS duration	98 ms
QT/QTc	430/414 ms
P-R-T axes	51 35 15

22 y.o. Black Male Soccer Player



ARS ECG #9:

Clear or Evaluate Further?

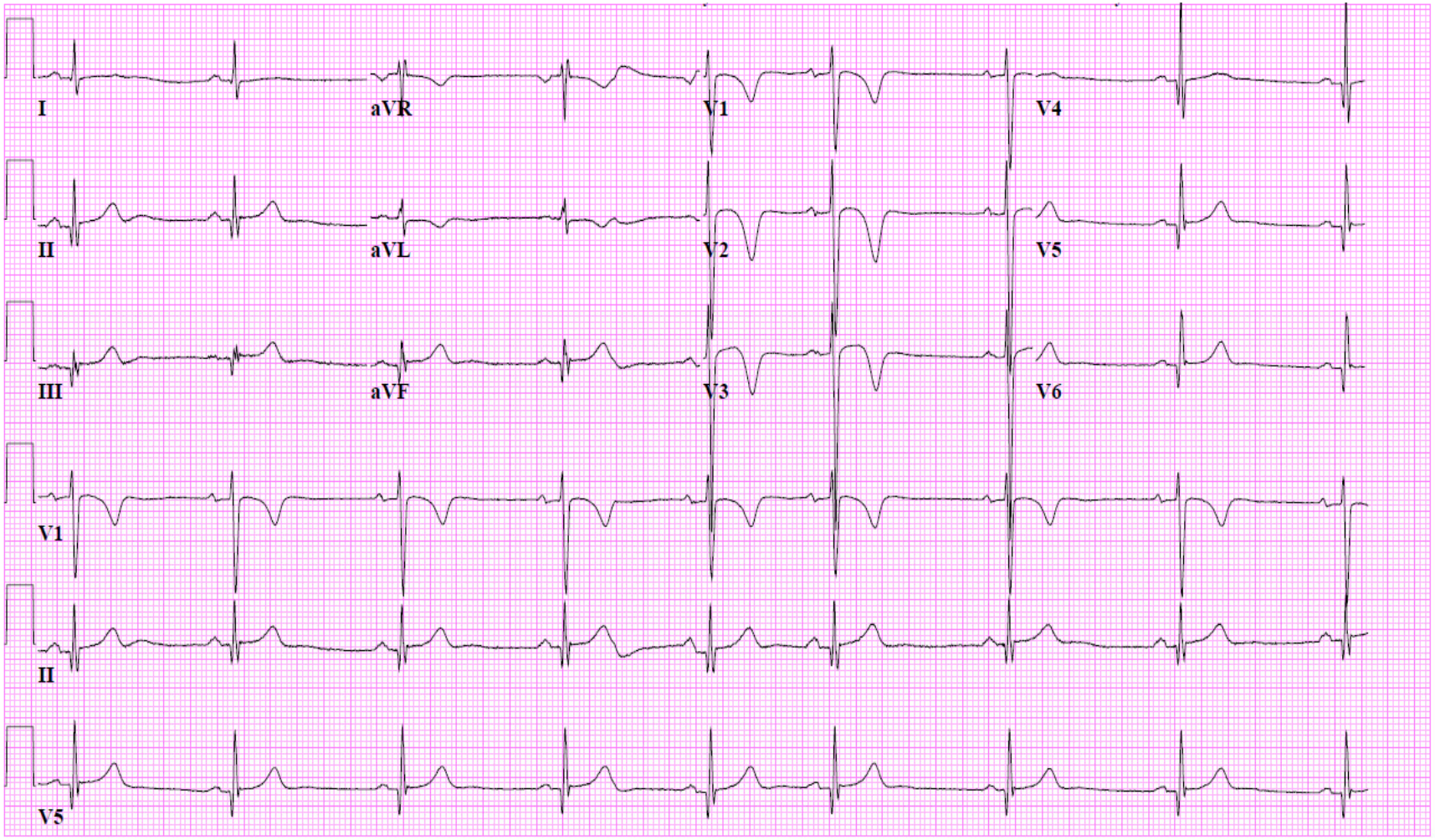

CNF i/o9

CNF i/o9 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#10

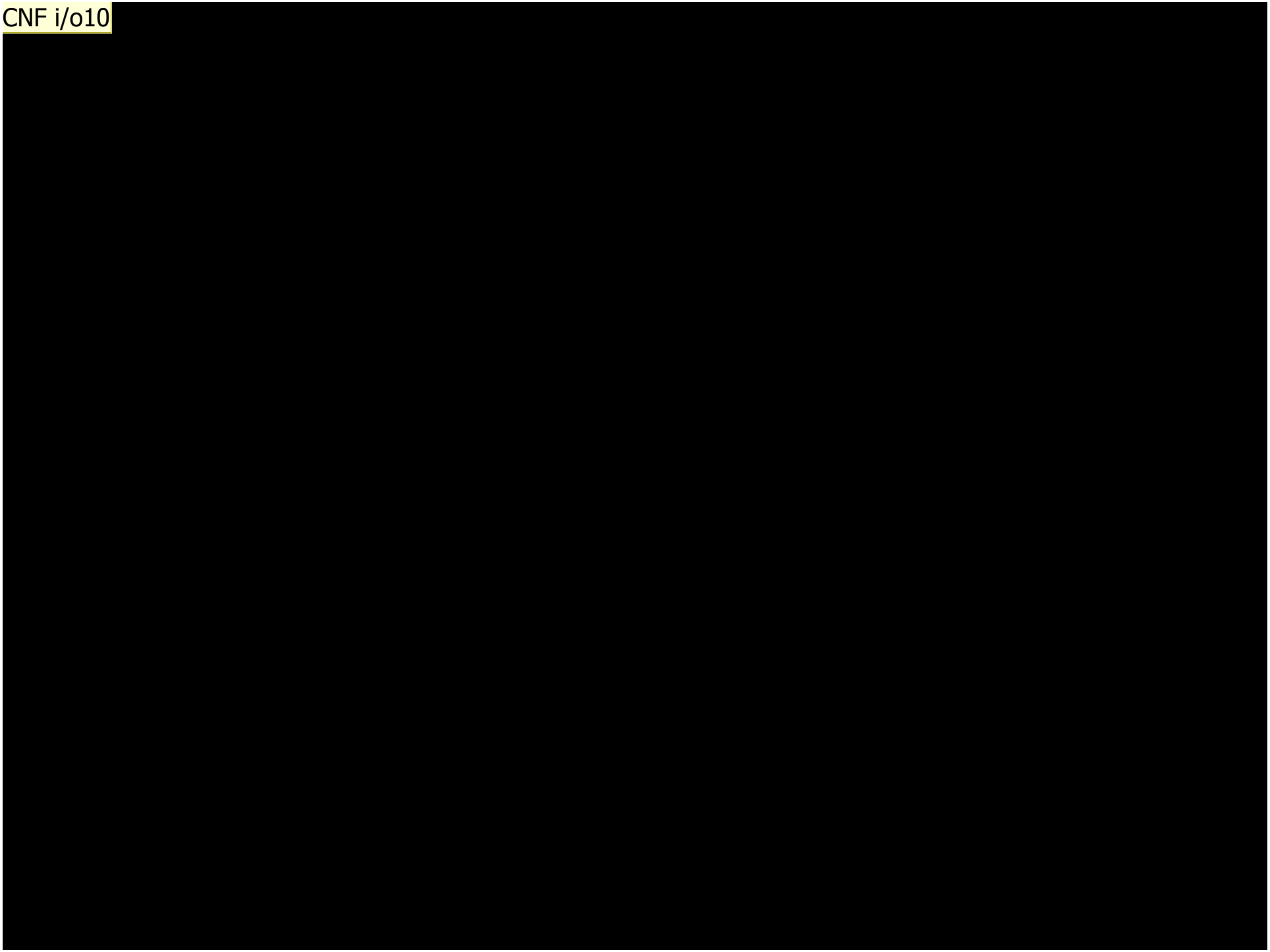
Vent. rate	50	BPM
PR interval	170	ms
QRS duration	90	ms
QT/QTc	442/402	ms
P-R-T axes	45 31	81

22 y.o. White Female Soccer Player



ARS ECG #10:

Clear or Evaluate Further?

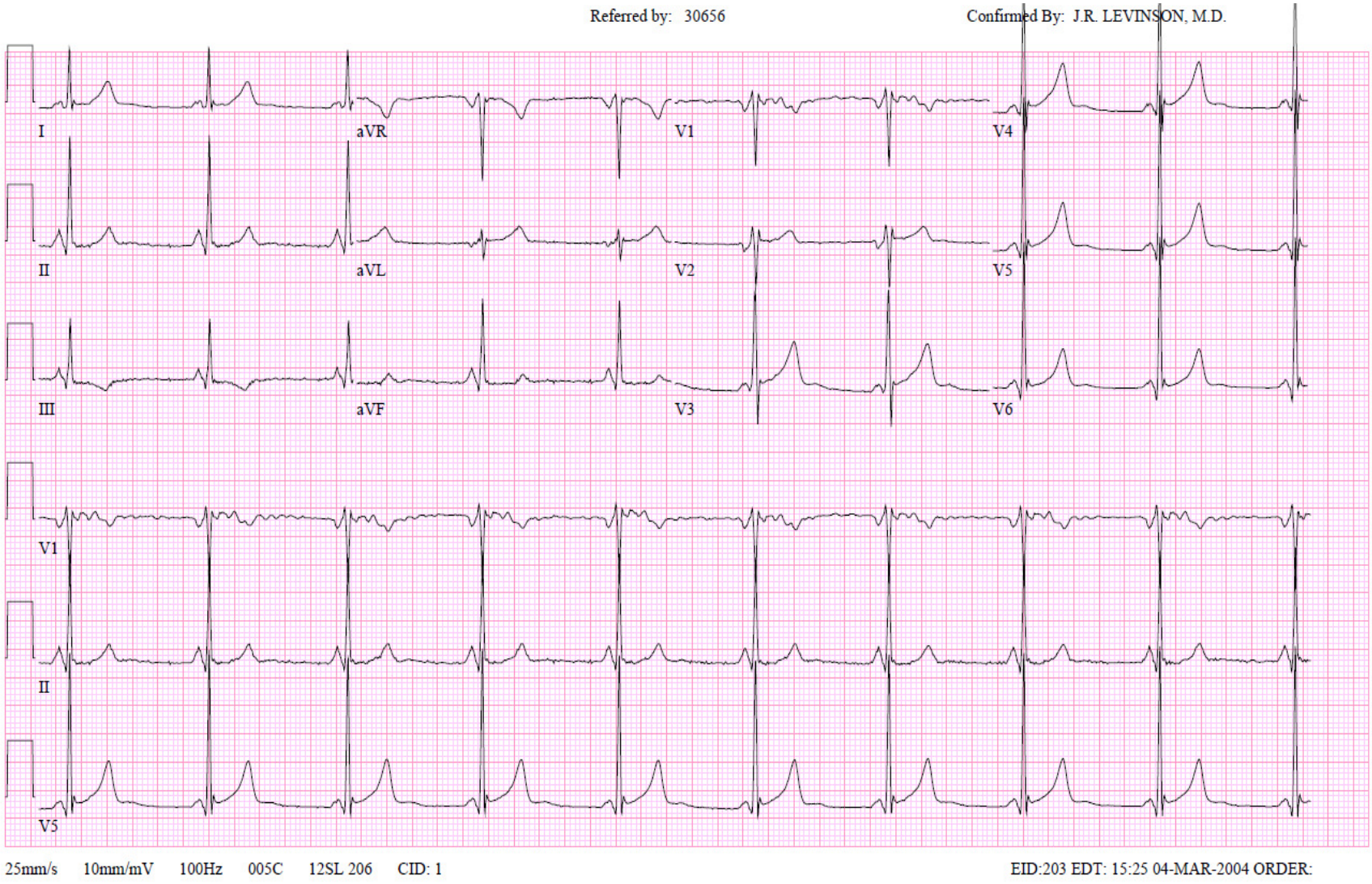

CNF i/o10

CNF i/o10 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#11

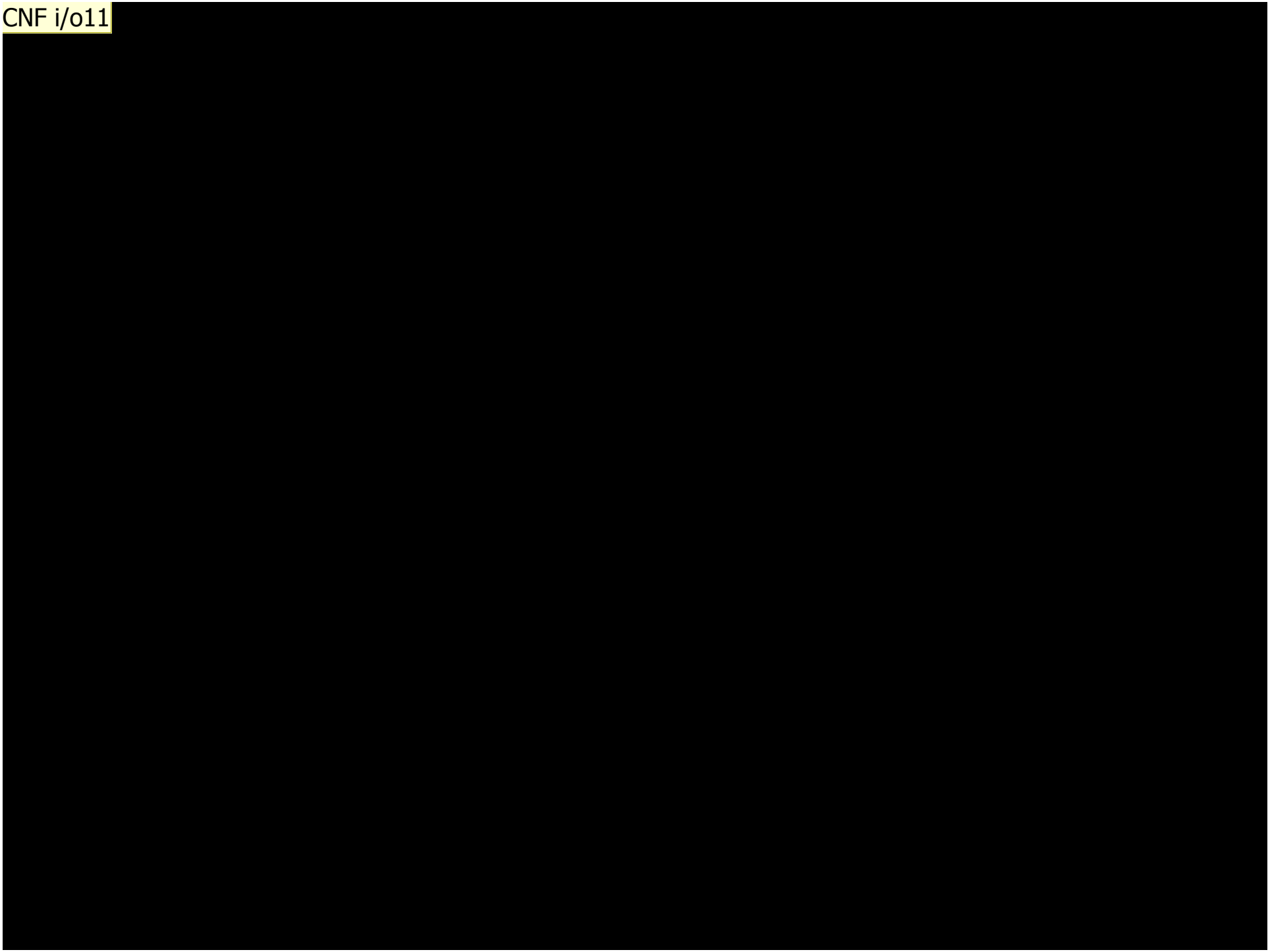
Vent. rate	56	BPM
PR interval	100	ms
QRS duration	112	ms
QT/QTc	436/421	ms
P-R-T axes	240 60	-28

19 y.o. White Female Rower



ARS ECG #11:

Clear or Evaluate Further?

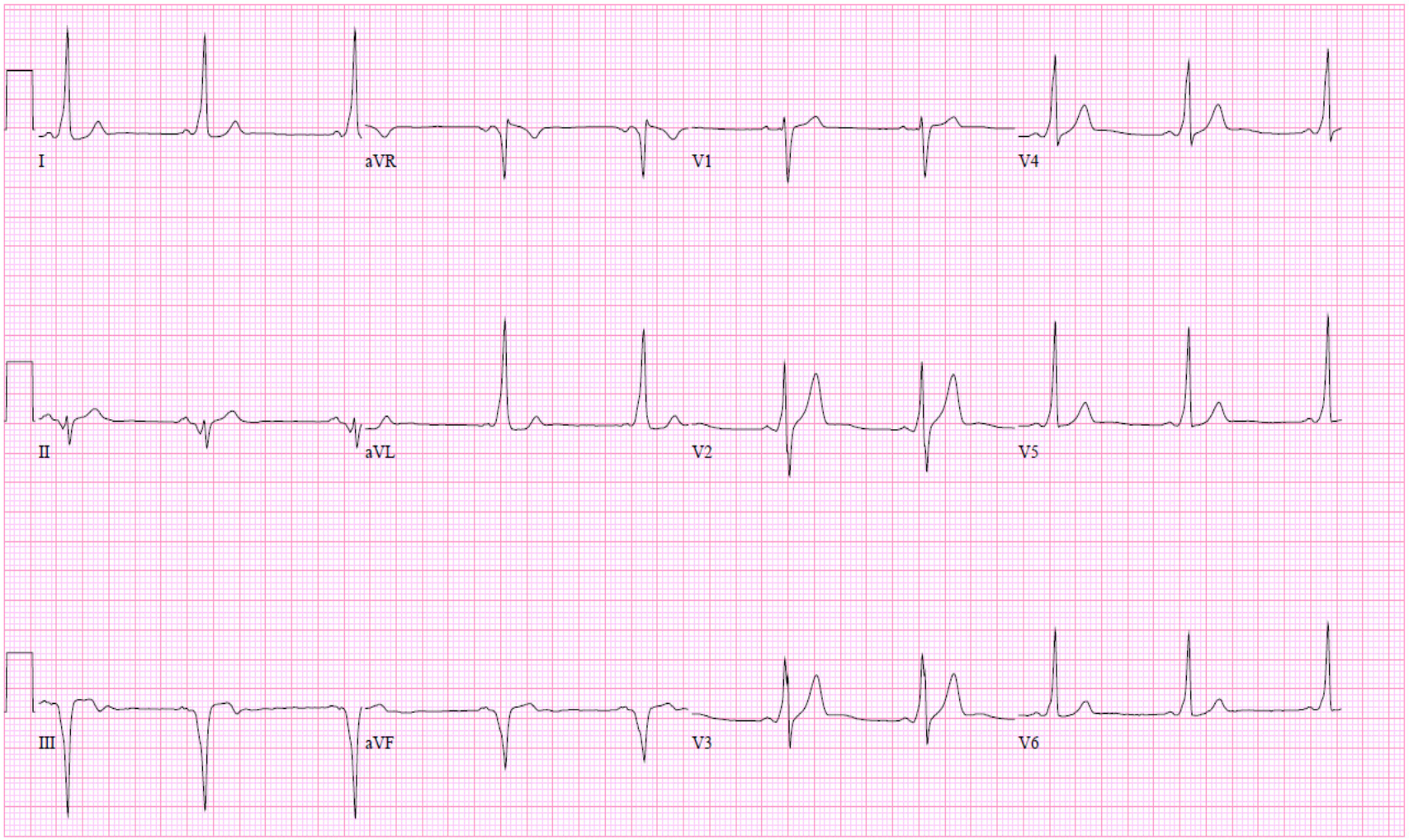

CNF i/o11

CNF i/o11 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#12

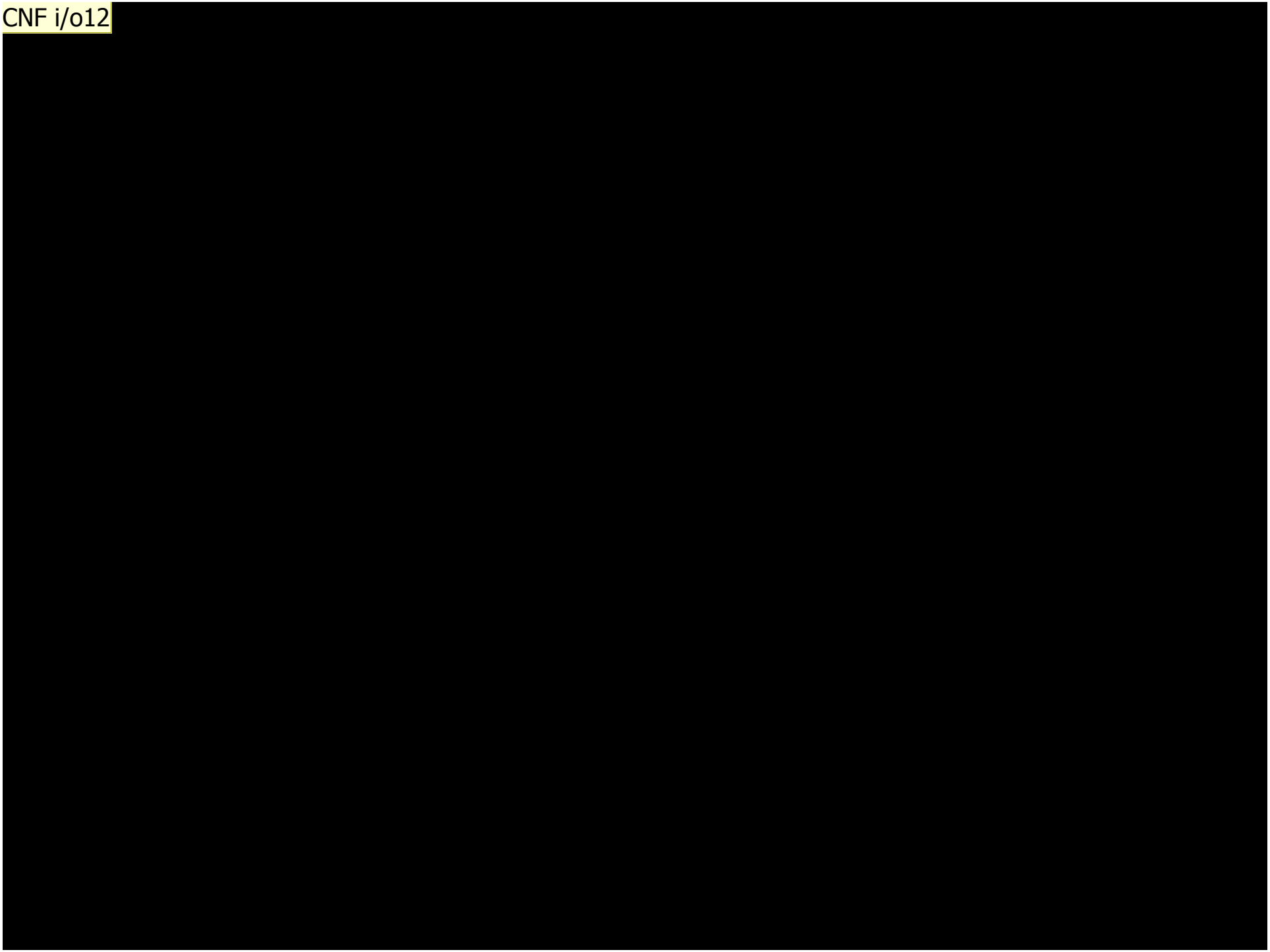
Vent. rate	55	BPM
PR interval	116	ms
QRS duration	132	ms
QT/QTc	400/382	ms
P-R-T axes	48 -36	19

19 y.o. White Male Distance Runner



ARS ECG #12:

Clear or Evaluate Further?

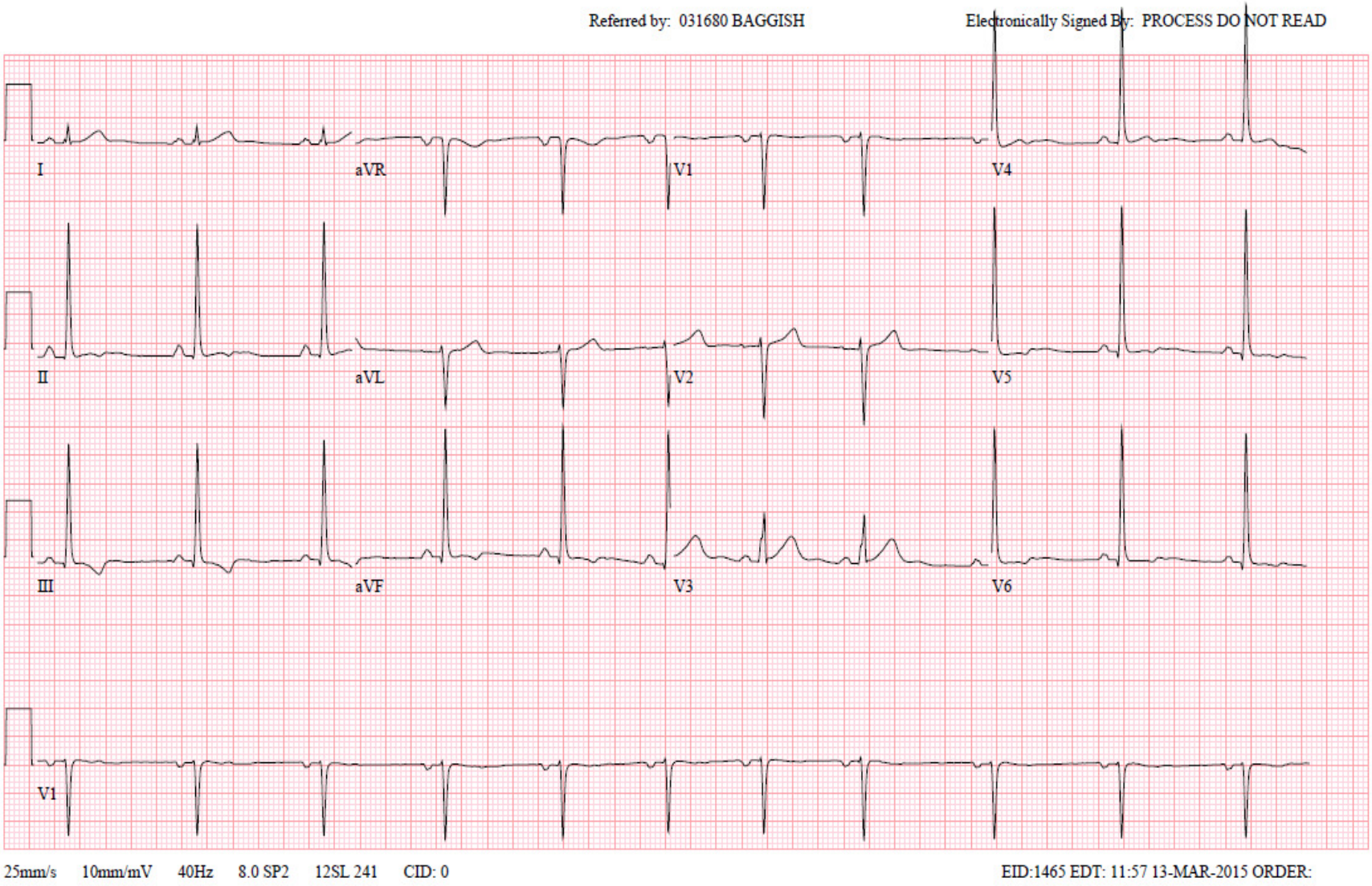

CNF i/o12

CNF i/o12 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#14

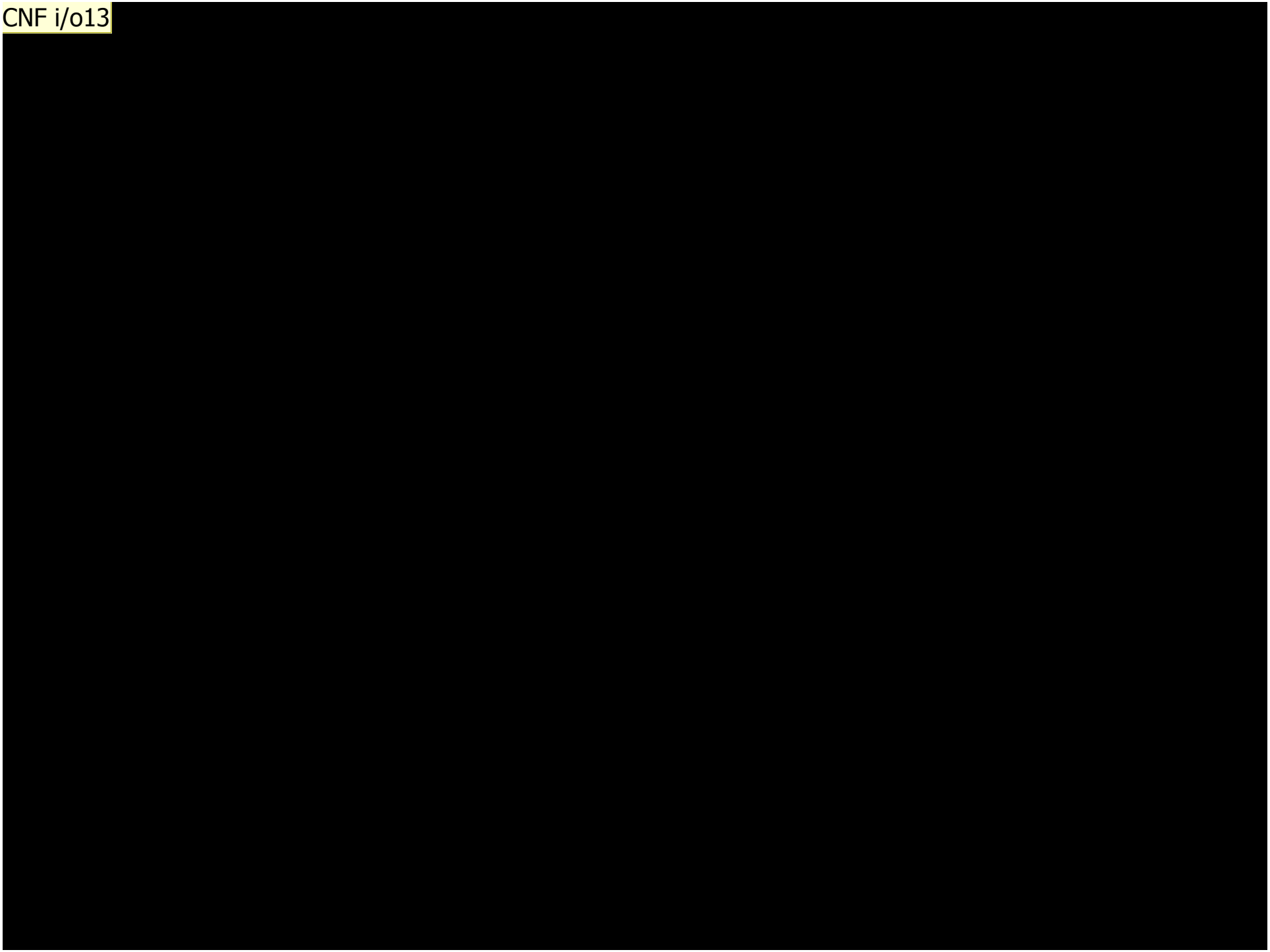
Vent. rate	65	BPM
PR interval	152	ms
QRS duration	88	ms
QT/QTc	370/384	ms
P-R-T axes	59 84	-3

20 y.o. White Male Football Player



ARS ECG #13:

Clear or Evaluate Further?

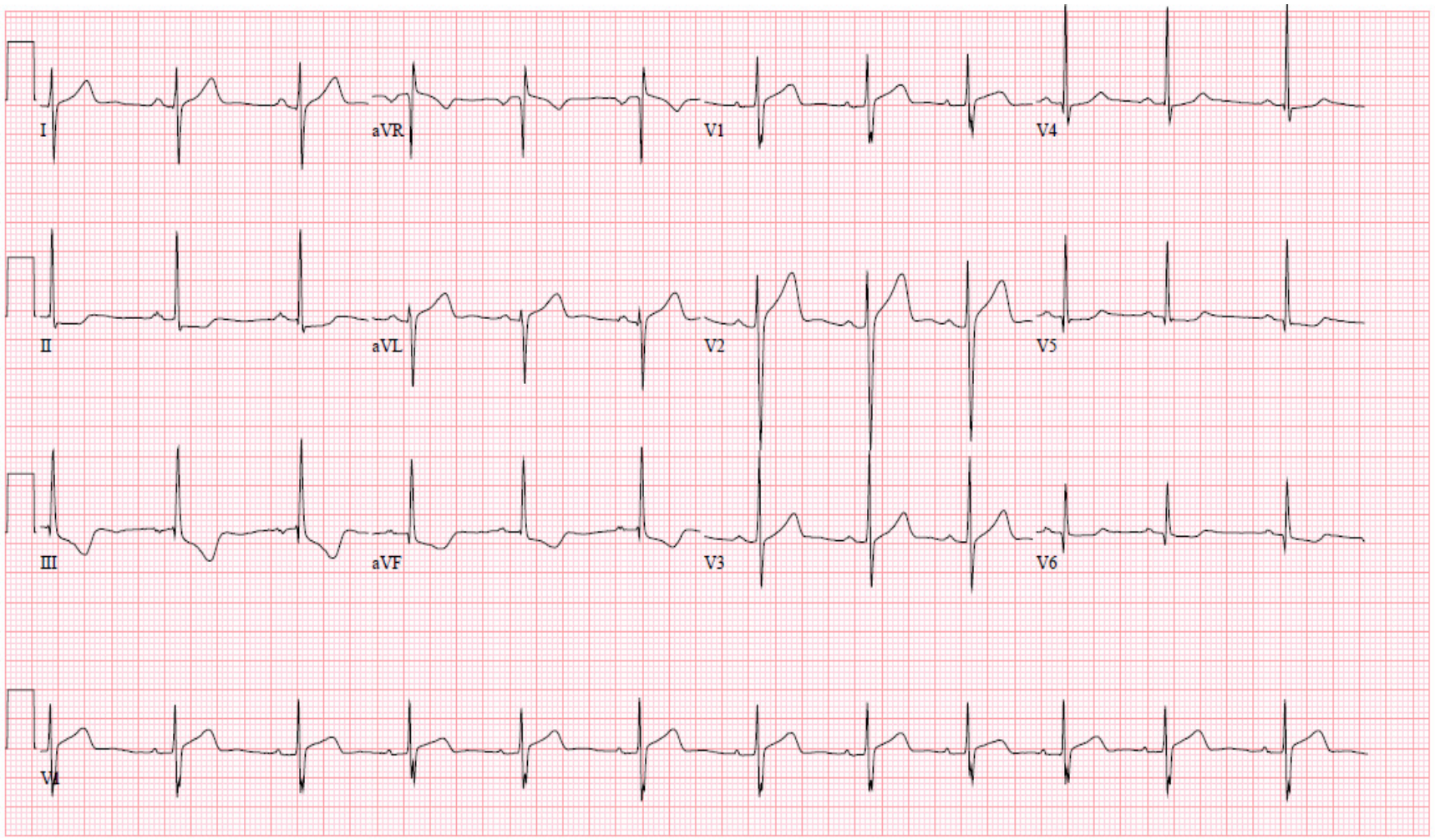

CNF i/o13

CNF i/o13 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#14

Vent. rate	71	BPM
PR interval	168	ms
QRS duration	78	ms
QT/QTc	390/423	ms
P-R-T axes	26 99	-34

20 y.o. White Female Basketball Player



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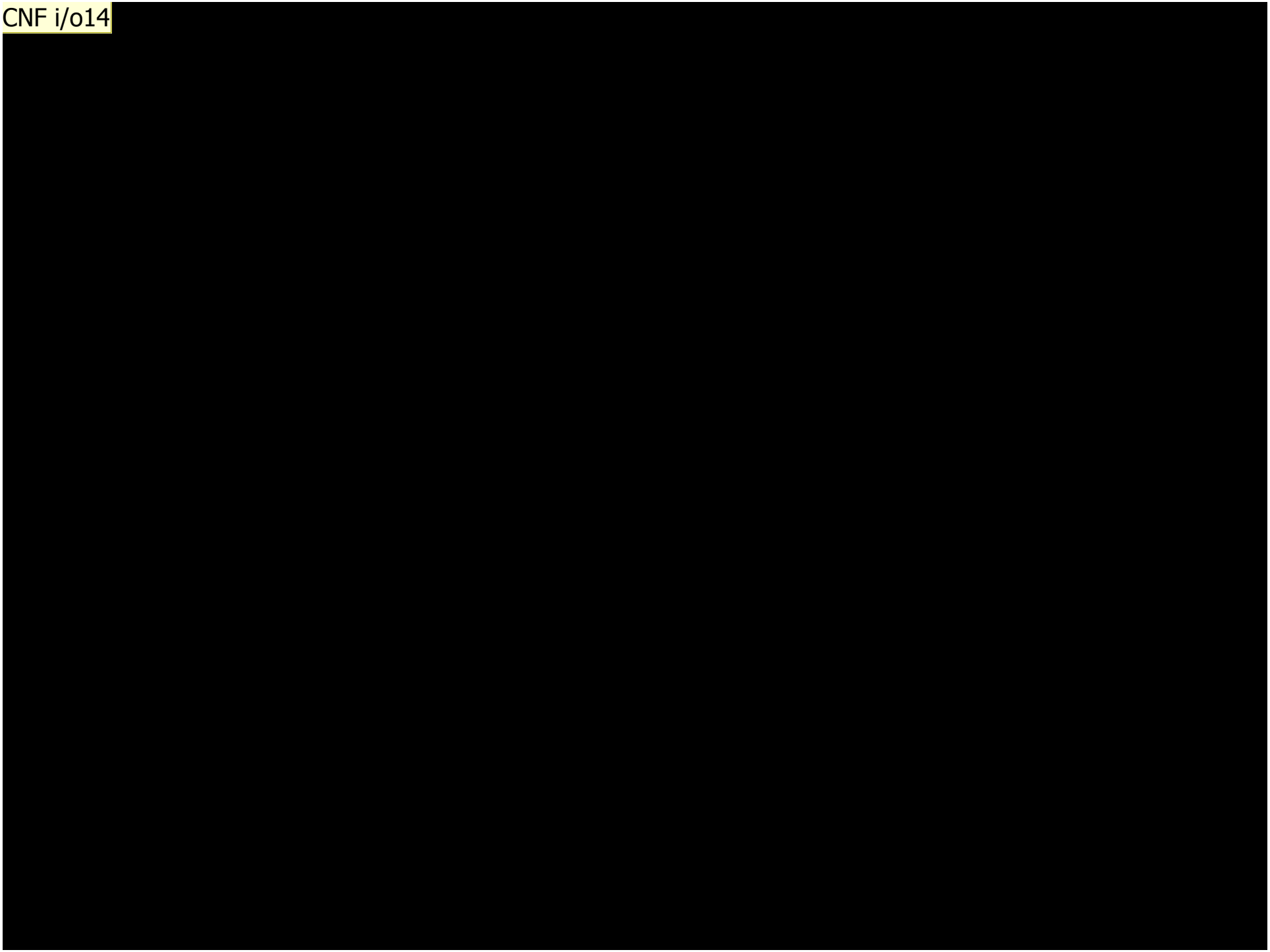
EID:1465 EDT: 07:34 24-DEC-2014 ORDER:

ARS ECG #14:

Clear or Evaluate Further?

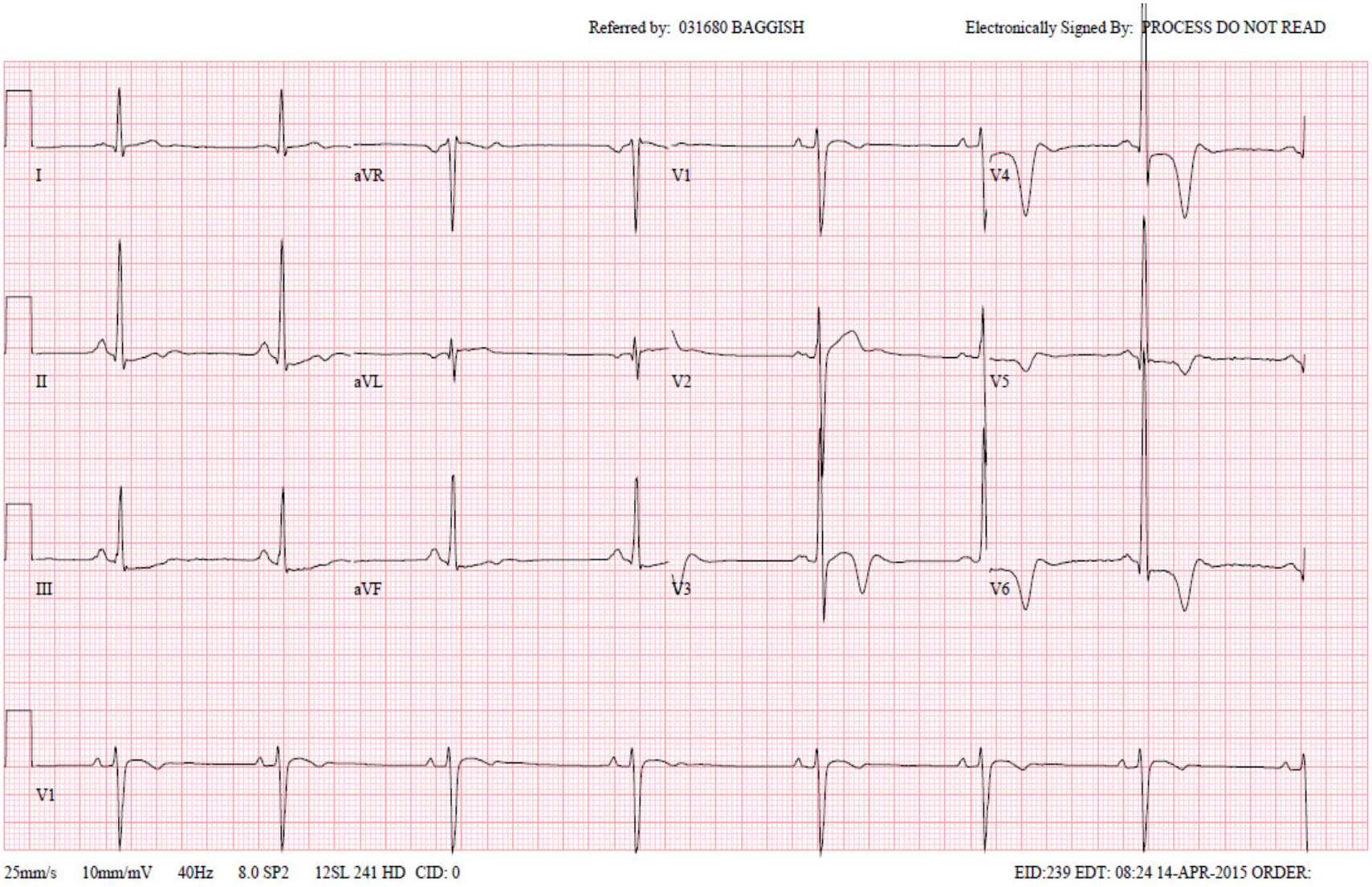

CNF i/o14

CNF i/o14 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#15

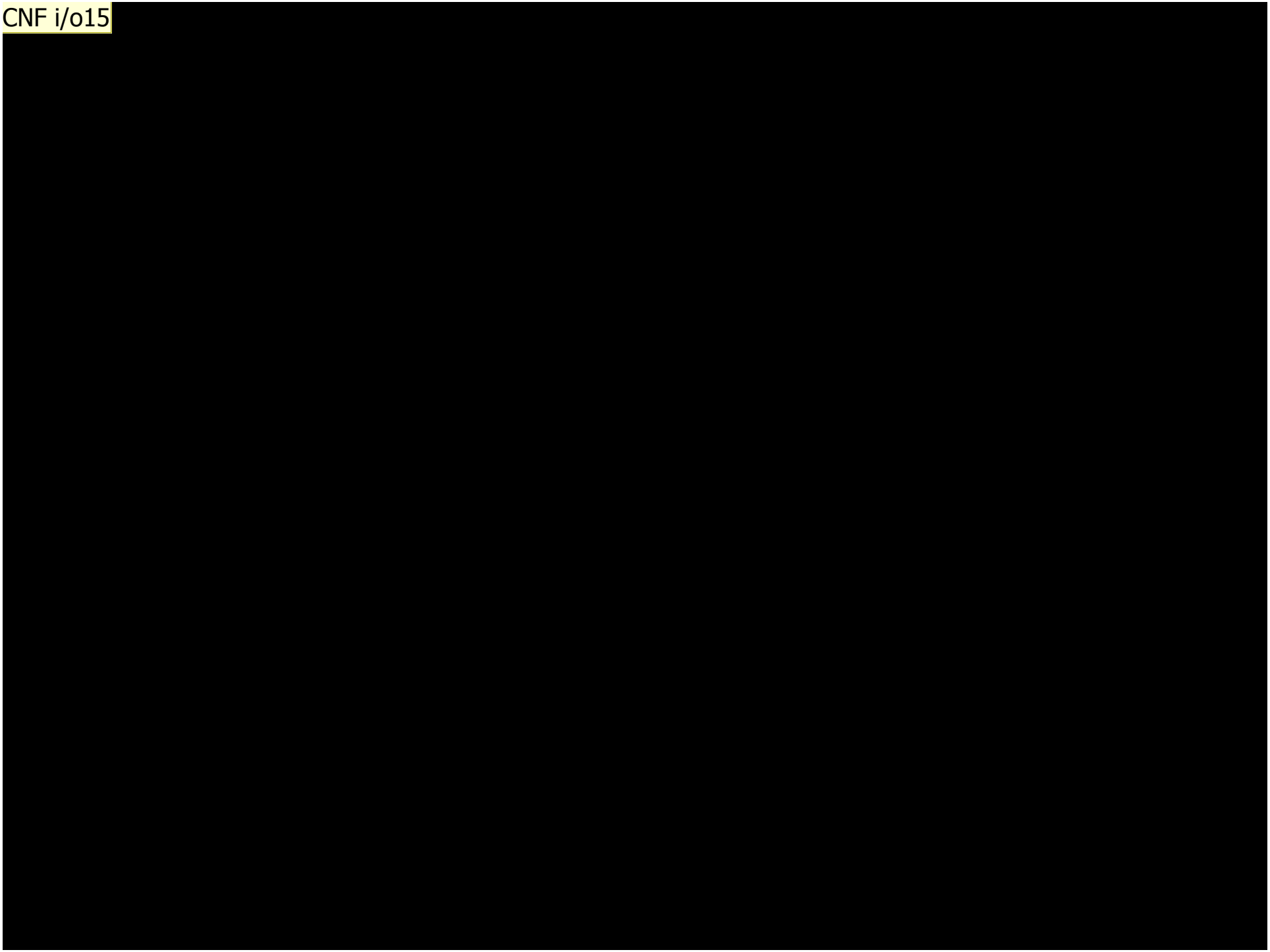
Vent. rate	45	BPM
PR interval	164	ms
QRS duration	110	ms
QT/QTc	478/413	ms
P-R-T axes	76 64	-10

26 y.o. White Male Triathlete



ARS ECG #15:

Clear or Evaluate Further?


CNF i/o15

CNF i/o15 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#16

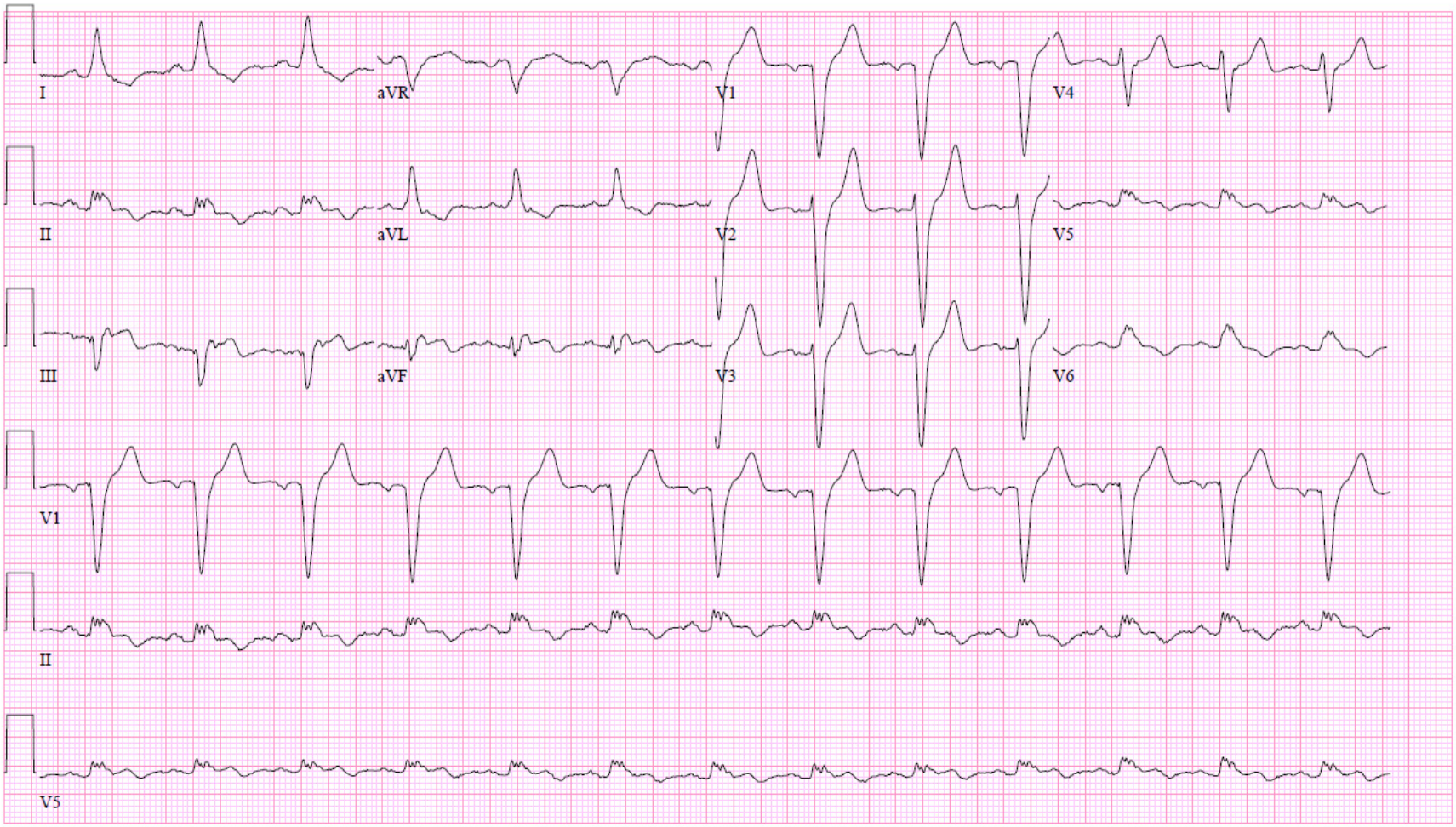
Vent. rate	79	BPM
PR interval	174	ms
QRS duration	140	ms
QT/QTc	438/502	ms
P-R-T axes	50 -9	174

21 y.o. White Male Middle Distance Runner

Technician: TN
Test ind:NOBILL

Referred by:

Confirmed By:



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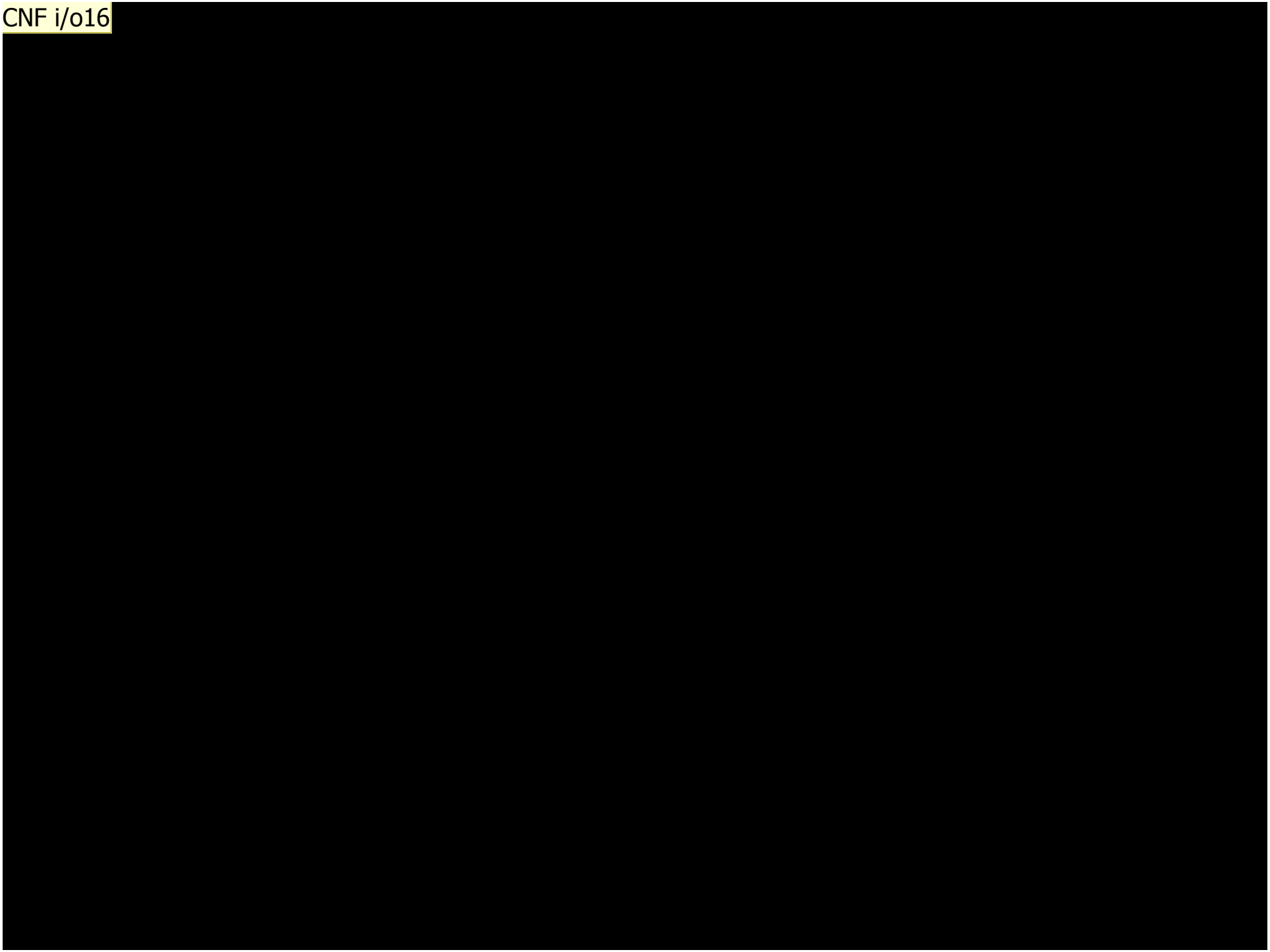
ARS ECG #16:

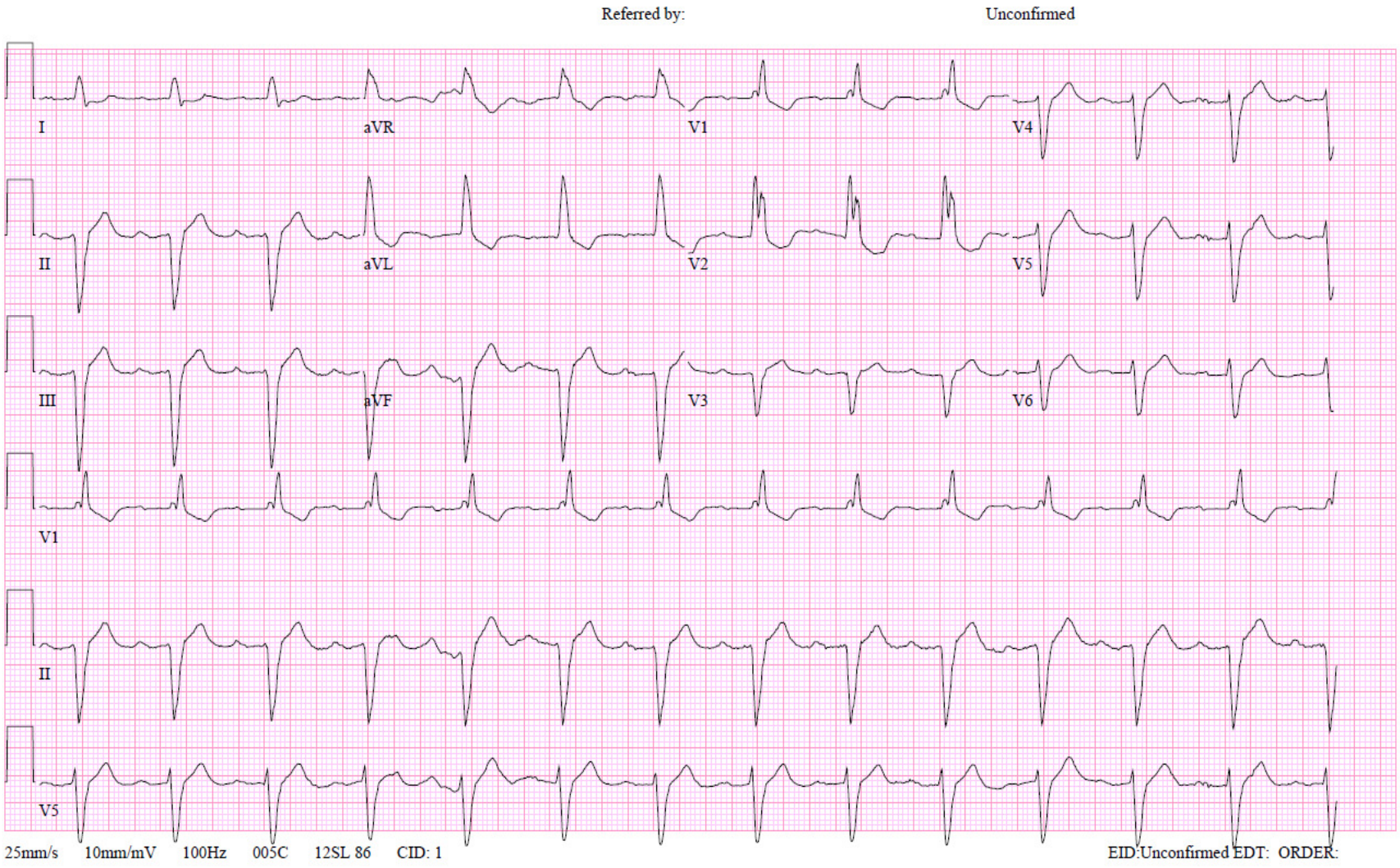
Clear or Evaluate Further?


CNF i/o16

CNF i/o16 Poll: What would you do?
CNF i/o, 6/16/2016

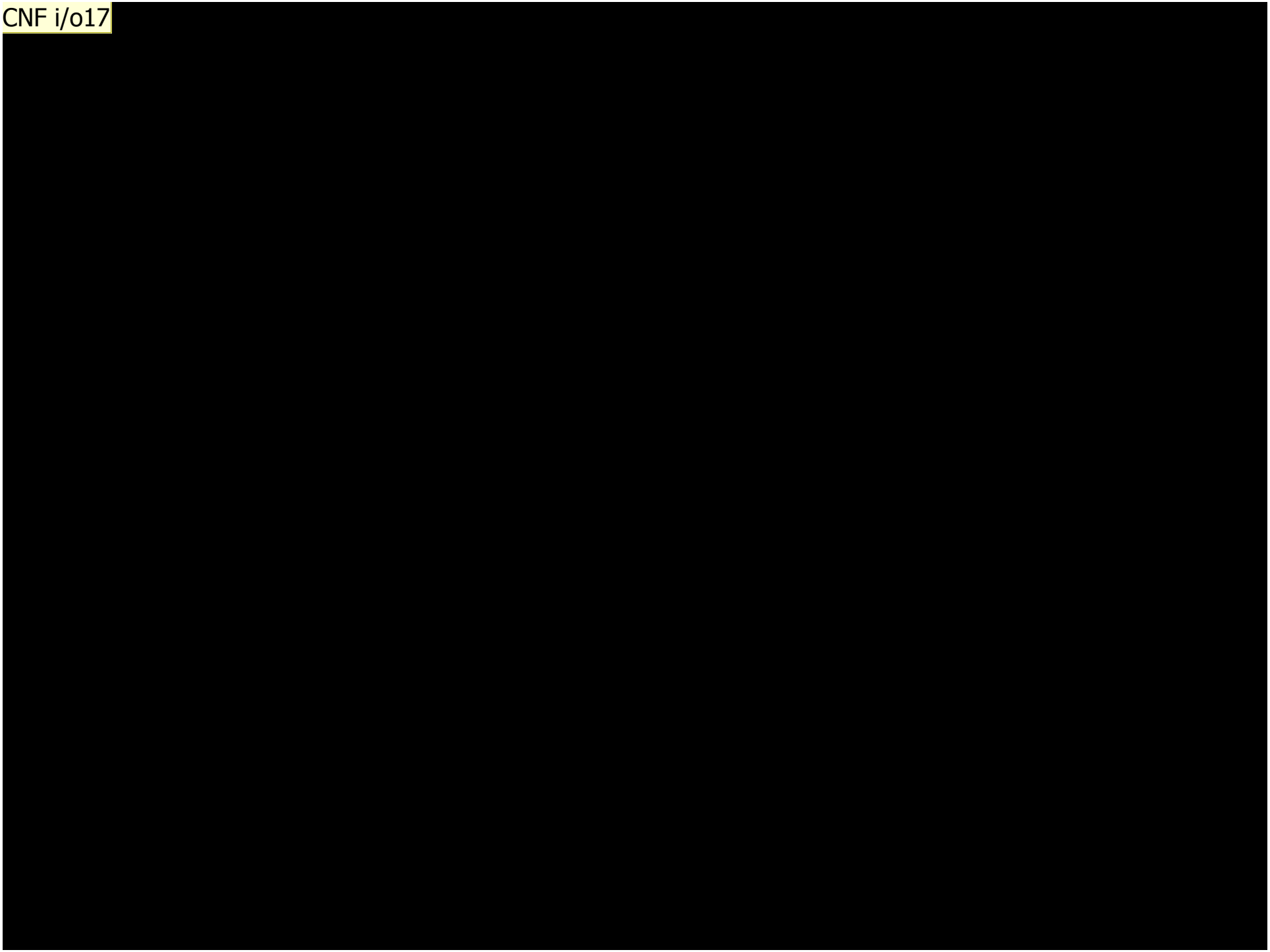
ECG#17

30 y.o. White Male Power Lifter



ARS ECG #17:

Clear or Evaluate Further?

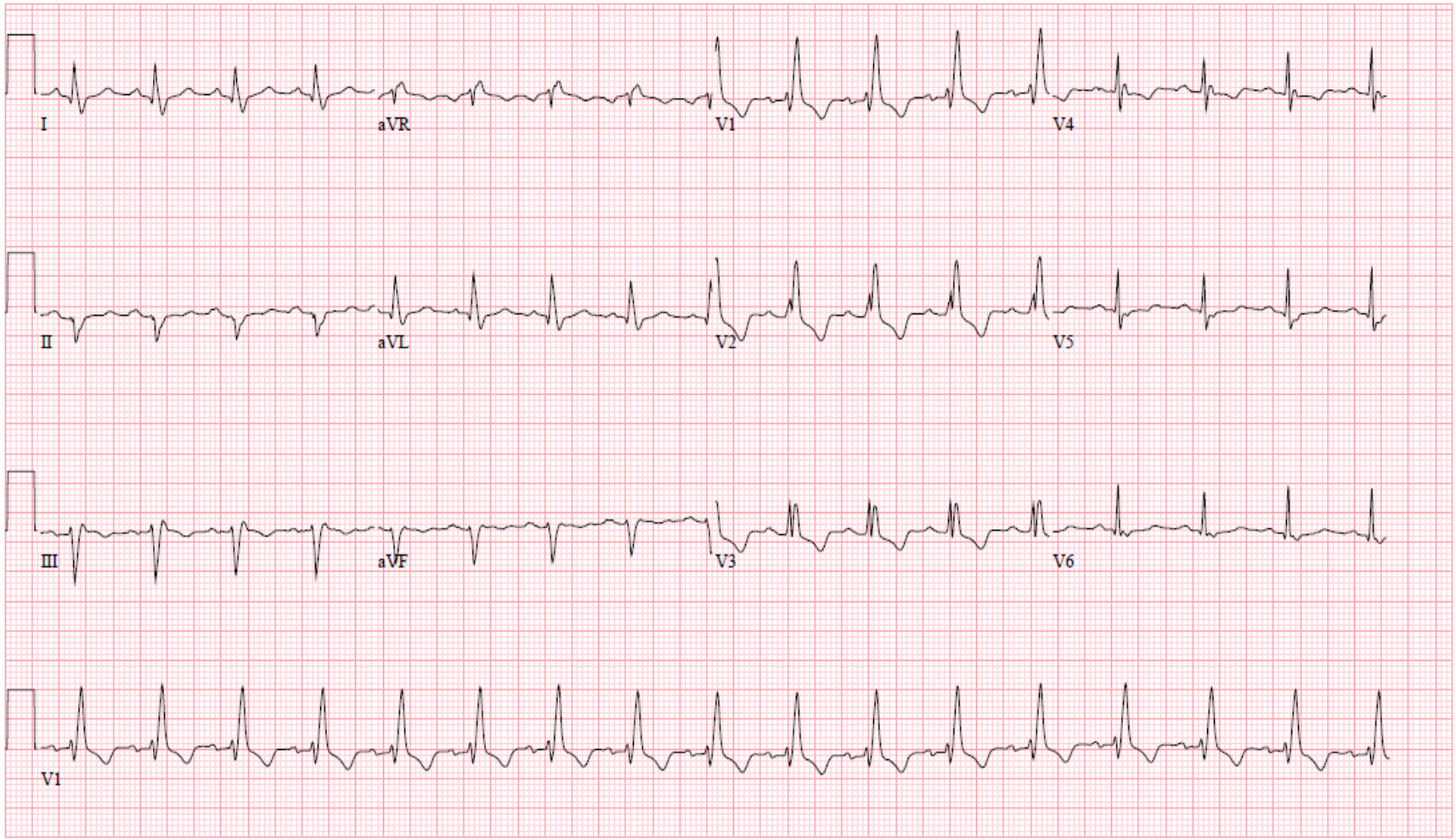

CNF i/o17

CNF i/o17 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#18

Vent. rate	100	BPM
PR interval	154	ms
QRS duration	134	ms
QT/QTc	374/482	ms
P-R-T axes	44 -66	16

21 y.o. White Male Rower

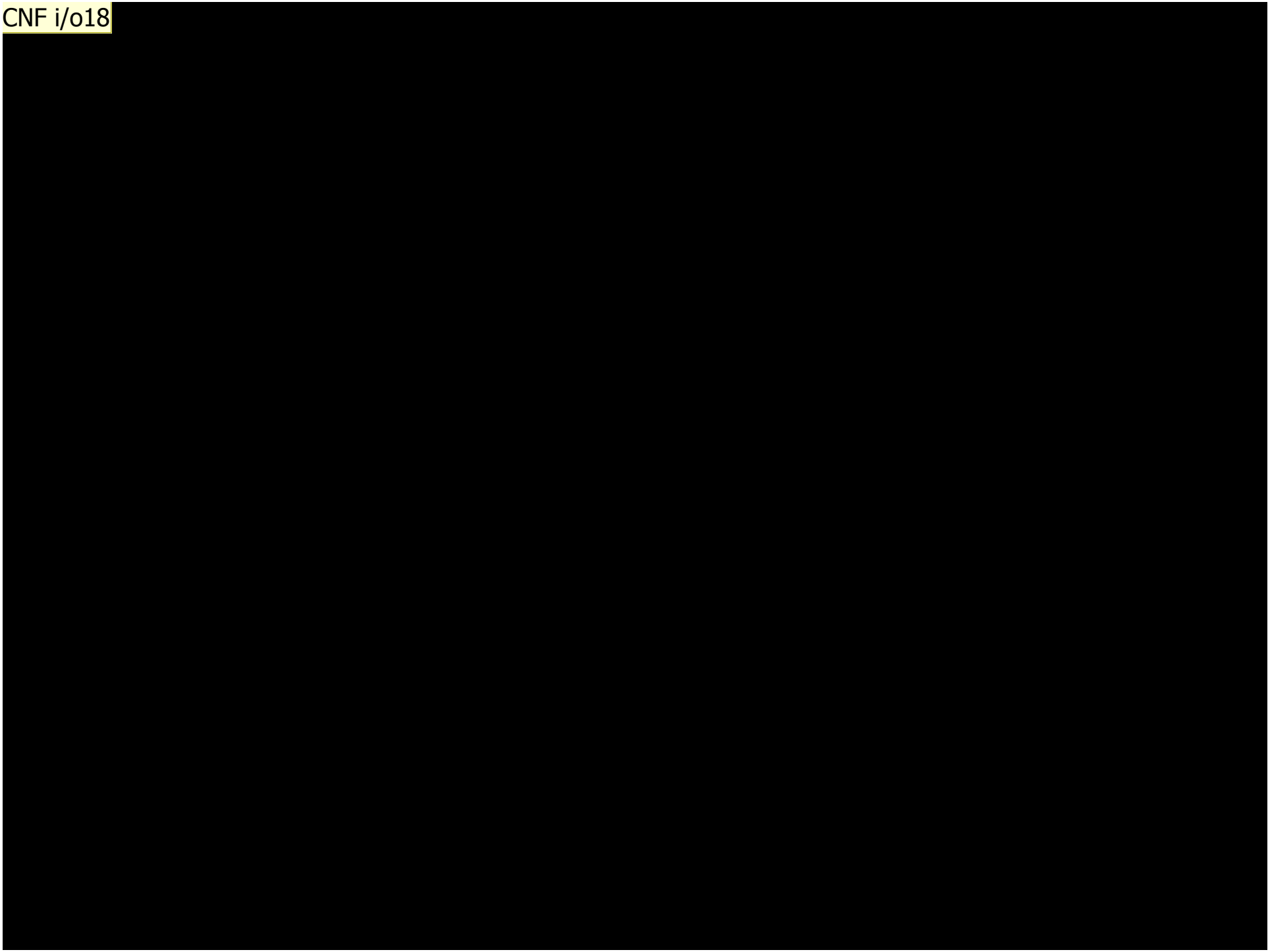


25mm/s 10mm/mV 40Hz 8.0 SP2 12SL 241 CID: 0

EID:202 EDT: 09:32 21-MAY-2013 ORDER:

ARS ECG #18:

Clear or Evaluate Further?

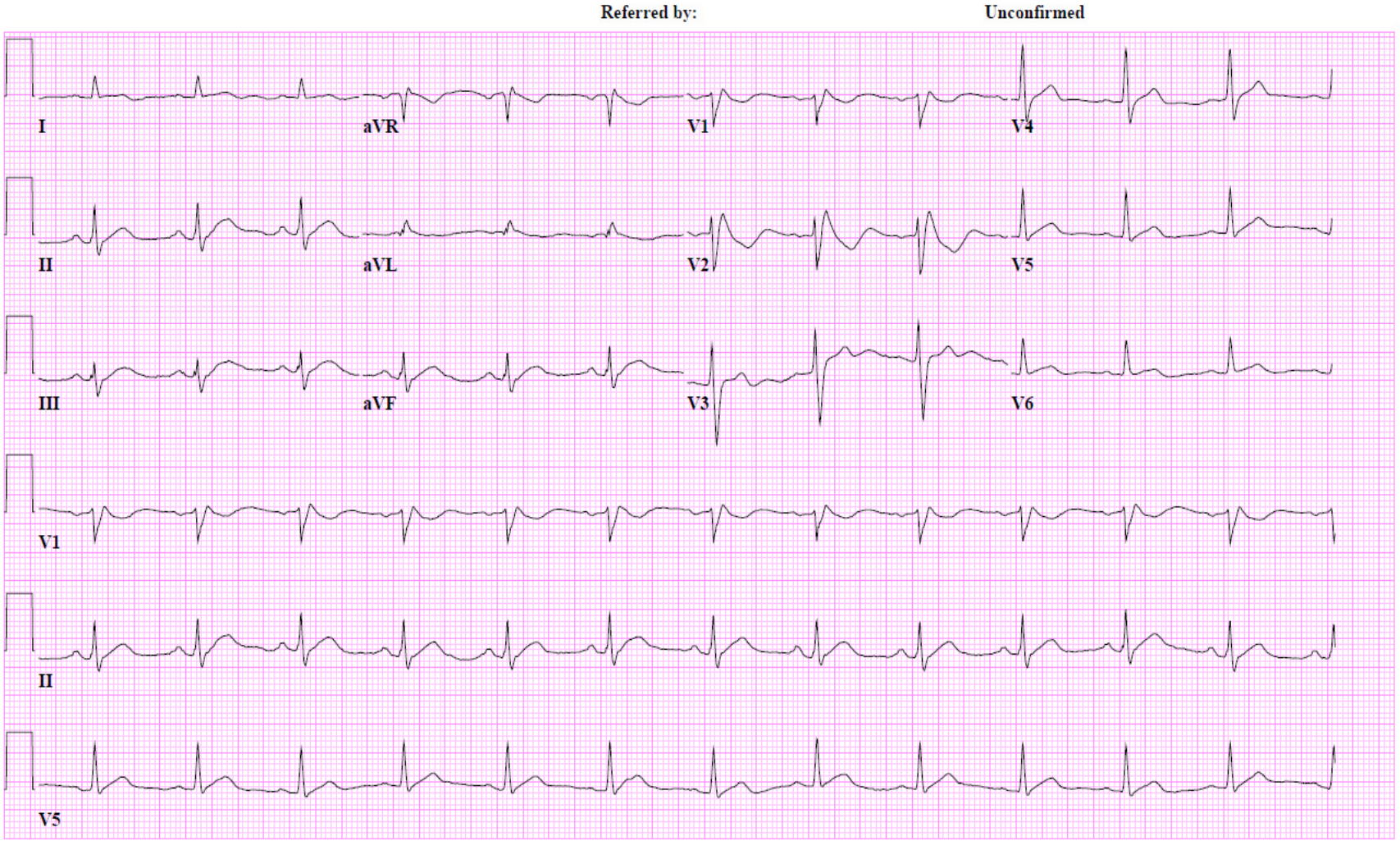

CNF i/o18

CNF i/o18 Poll: What would you do?
CNF i/o, 6/16/2016

ECG#19

Vent. rate	75	BPM
PR interval	175	ms
QRS duration	117	ms
QT/QTc	363/405	ms
P-R-T axes	78 36	85

24 y.o. Asian Male Golfer



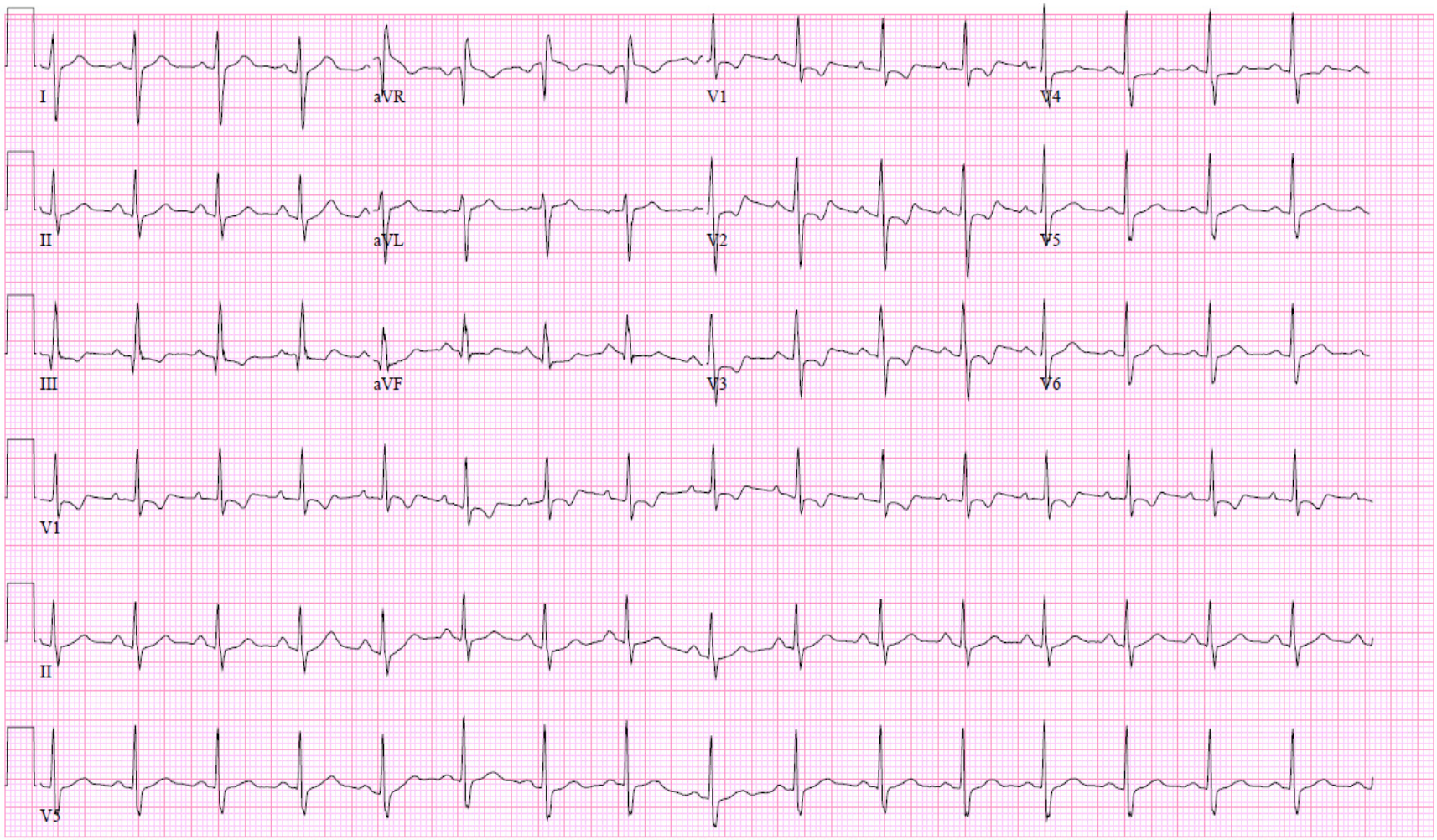
ARS ECG #19:

Clear or Evaluate Further?

ECG#20

Vent. rate	96	BPM
PR interval	146	ms
QRS duration	100	ms
QT/QTc	333/421	ms
P-R-T axes	60 117 27	

18 y.o. White Female Cheerleader



ARS ECG #20:

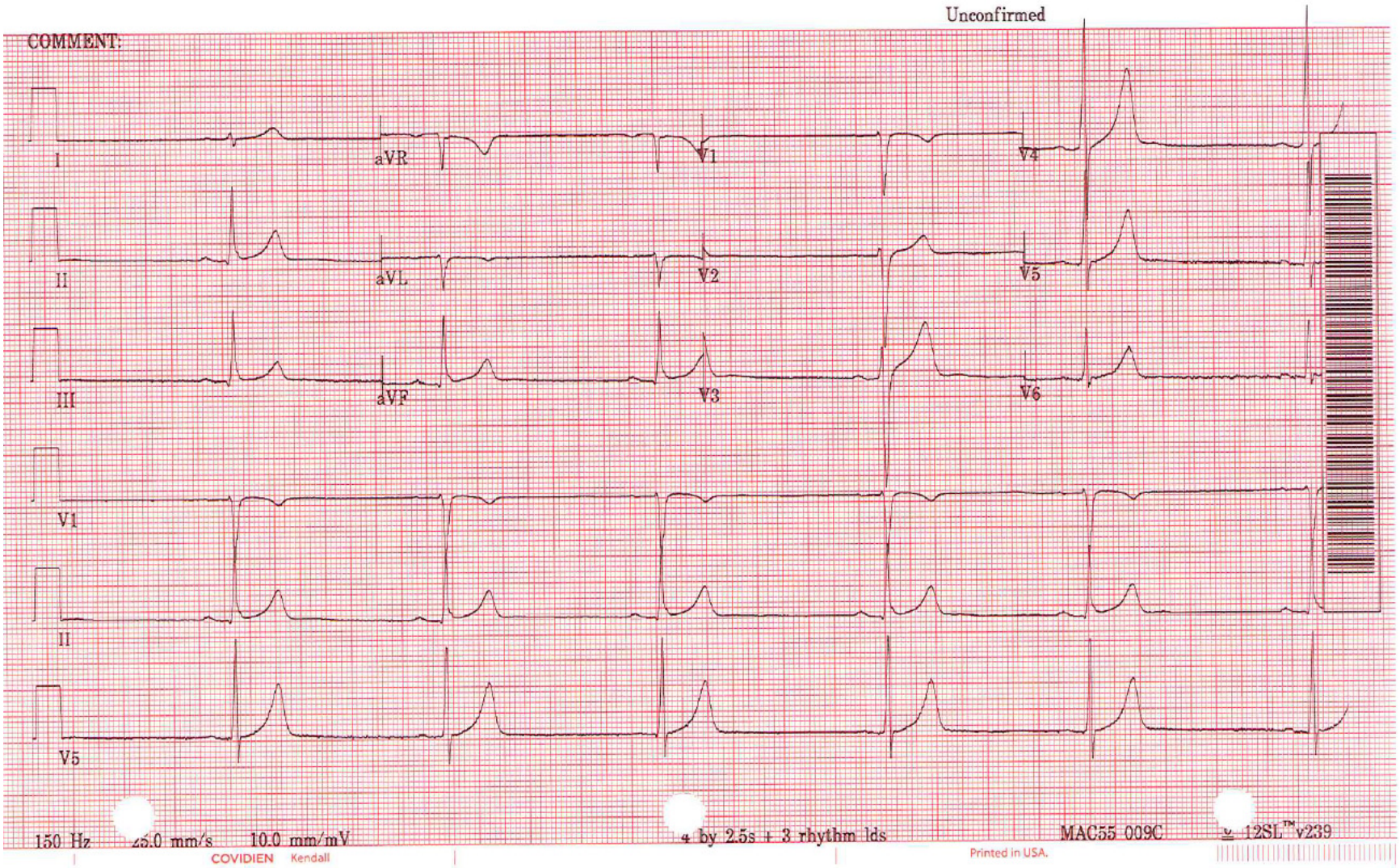
Clear or Evaluate Further?

Round 2

ECG#1

Vent. rate	36 bpm
PR interval	194 ms
QRS duration	118 ms
QT/QTc	492/380 ms
P-R-T axes	68 89 72

22 y.o. White Male Distance Runner



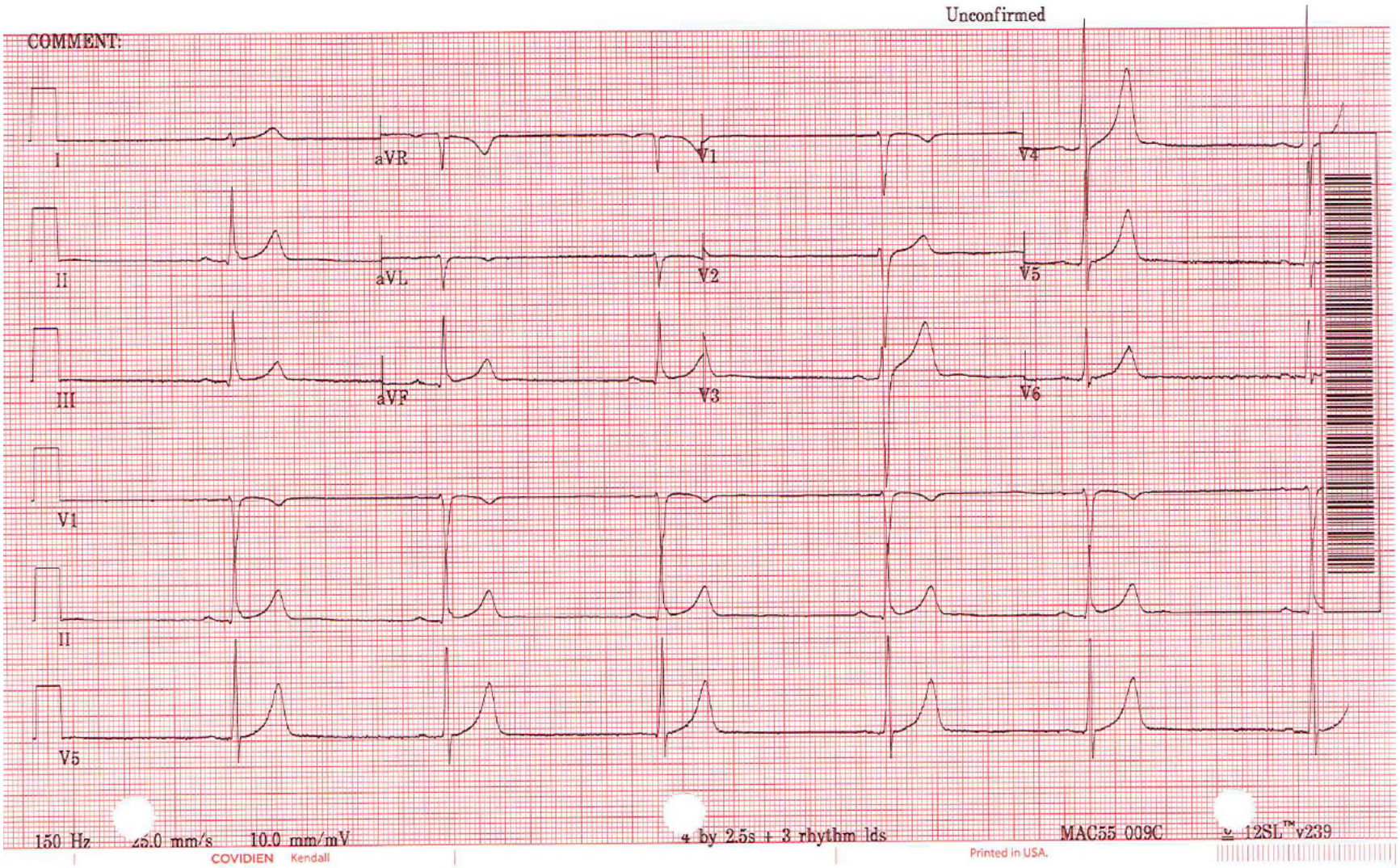
ARS ECG #1:

Audience Response

ECG#1

Vent. rate	36 bpm
PR interval	194 ms
QRS duration	118 ms
QT/QTc	492/380 ms
P-R-T axes	68 89 72

22 y.o. White Male Distance Runner



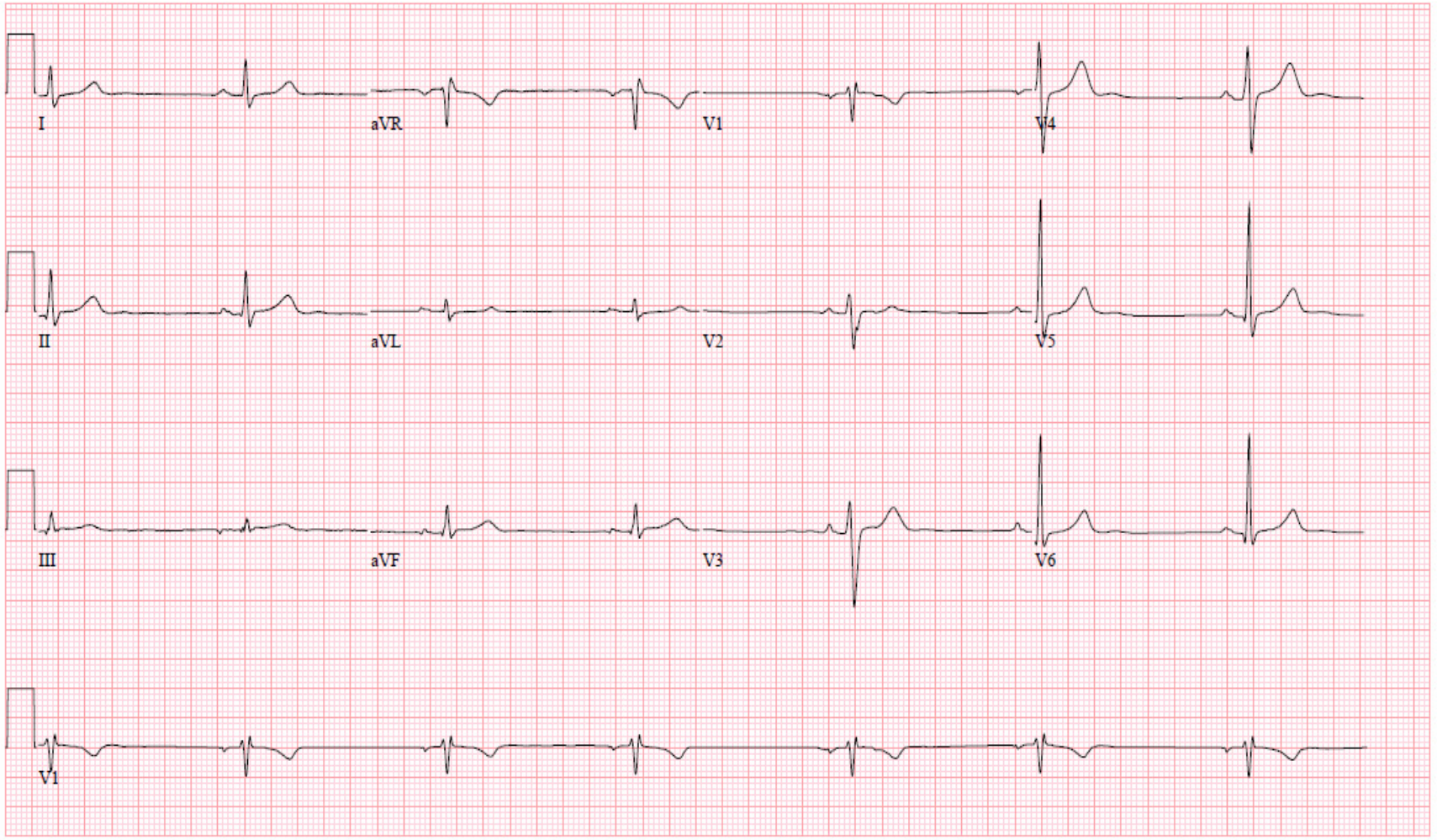
ECG#2

26 y.o. White Female Triathlete

Vent. rate	40
PR interval	170
QRS duration	114
QT/QTc	486/396
P-R-T axes	26 52

Referred by: 031680

Electronically Signed By: AARON L. BAGGISH, M.D.



25mm/s 10mm/mV 40Hz 8.0 SP2 12SL 241 HD CID: 0

EID:1470 EDT: 10:00 31-JUL-2015 ORDER:

ARS ECG #2:

Audience Response

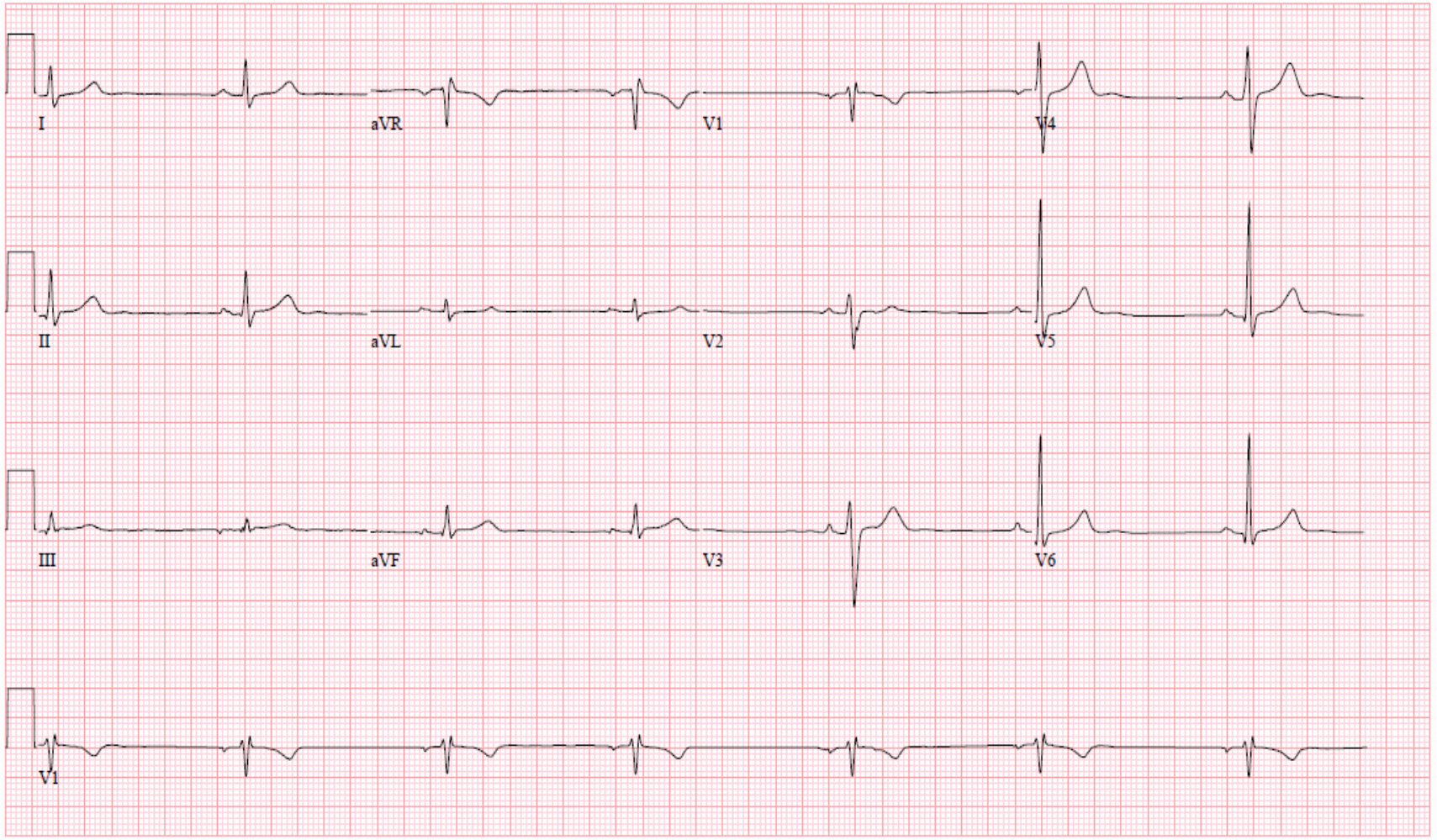
ECG#2

26 y.o. White Female Triathlete

Vent. rate	40
PR interval	170
QRS duration	114
QT/QTc	486/396
P-R-T axes	26 52

Referred by: 031680

Electronically Signed By: AARON L. BAGGISH, M.D.



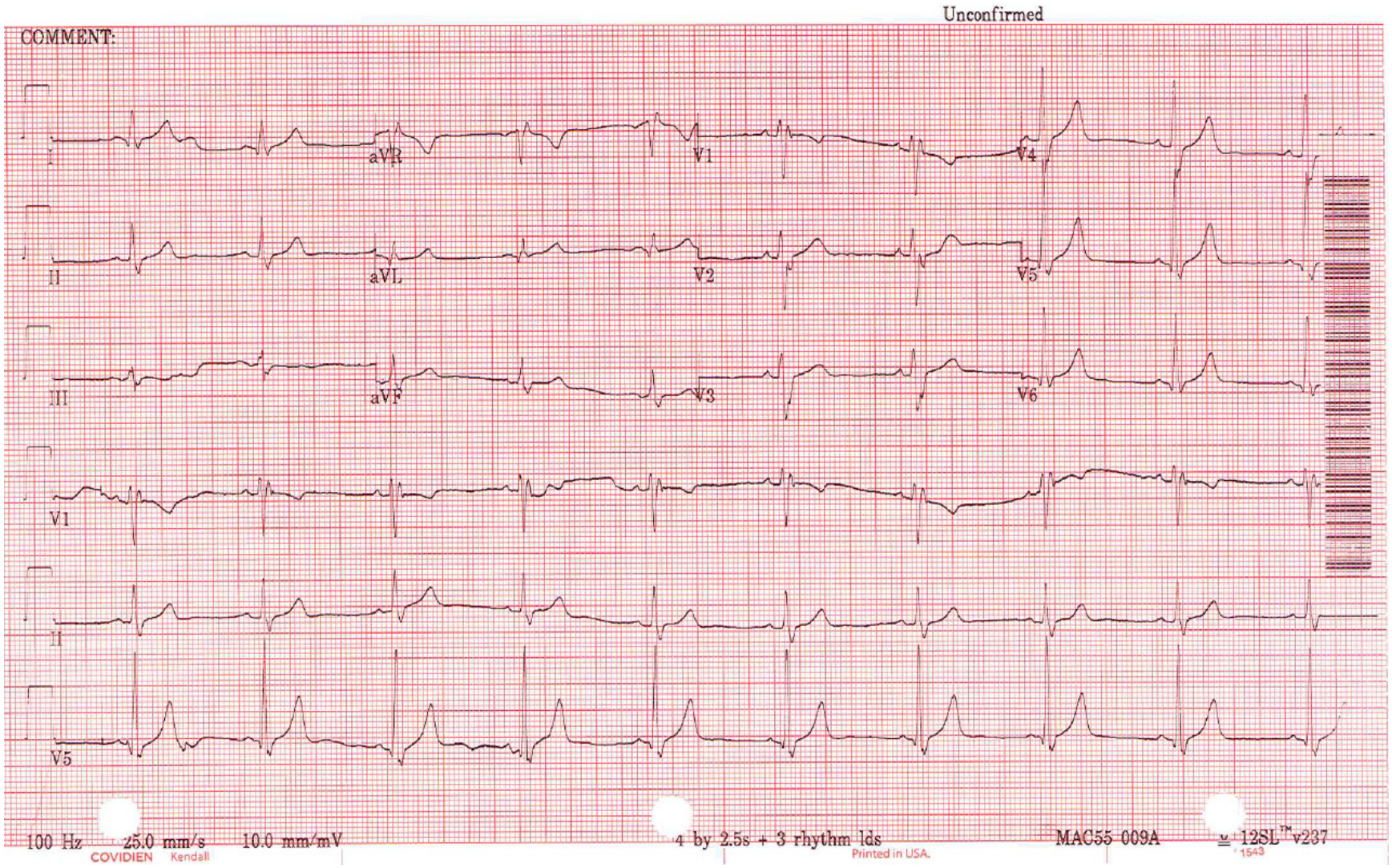
25mm/s 10mm/mV 40Hz 8.0 SP2 12SL 241 HD CID: 0

EID:1470 EDT: 10:00 31-JUL-2015 ORDER:

ECG#3

Vent. rate	59 bpm
PR interval	120 ms
QRS duration	118 ms
QT/QTc	412/407 ms
P-R-T axes	28 33 27

18 y.o. Black Male Lacrosse Player



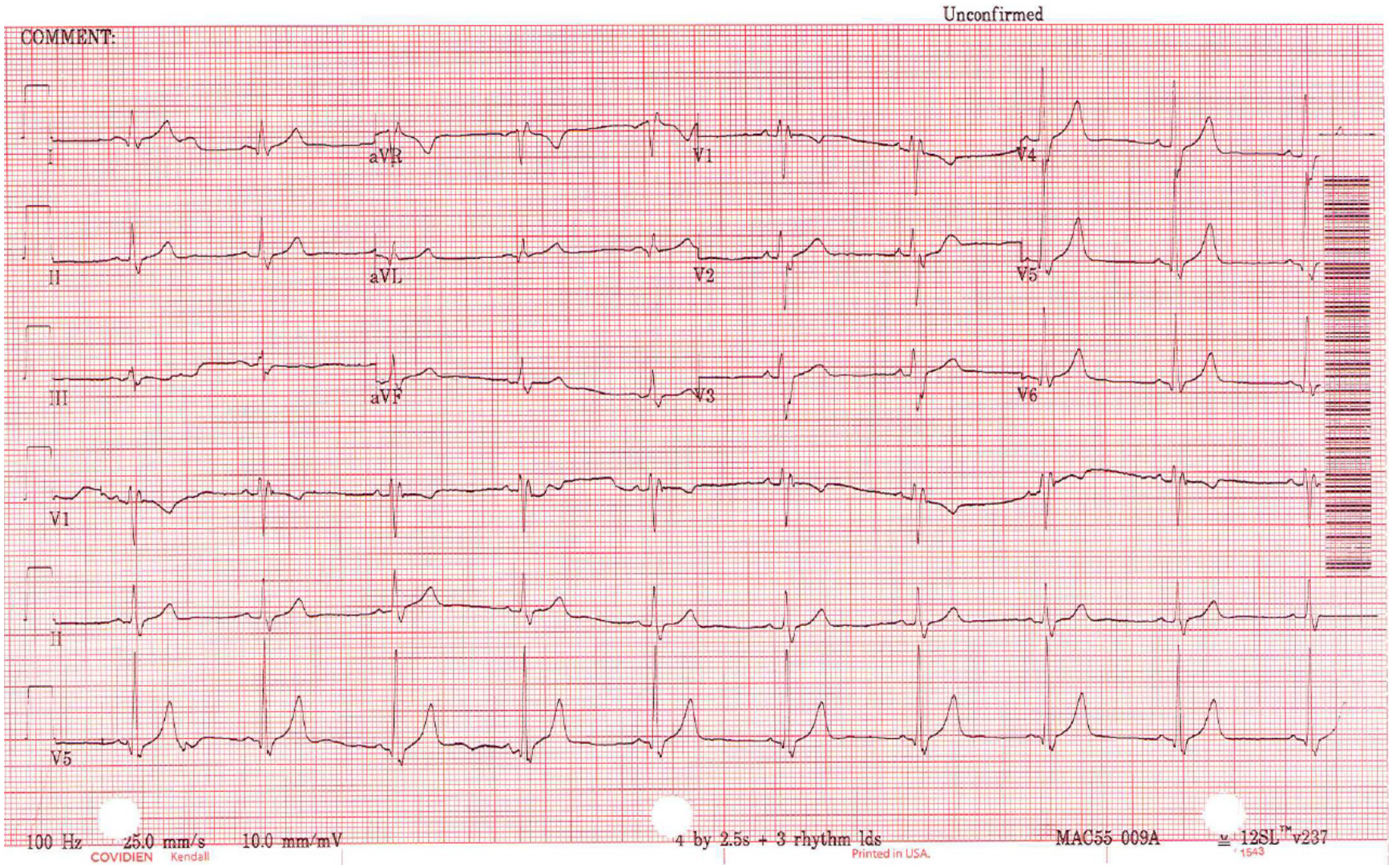
ARS ECG #3:

Audience Response

ECG#3

Vent. rate	59 bpm
PR interval	120 ms
QRS duration	118 ms
QT/QTc	412/407 ms
P-R-T axes	28 33 27

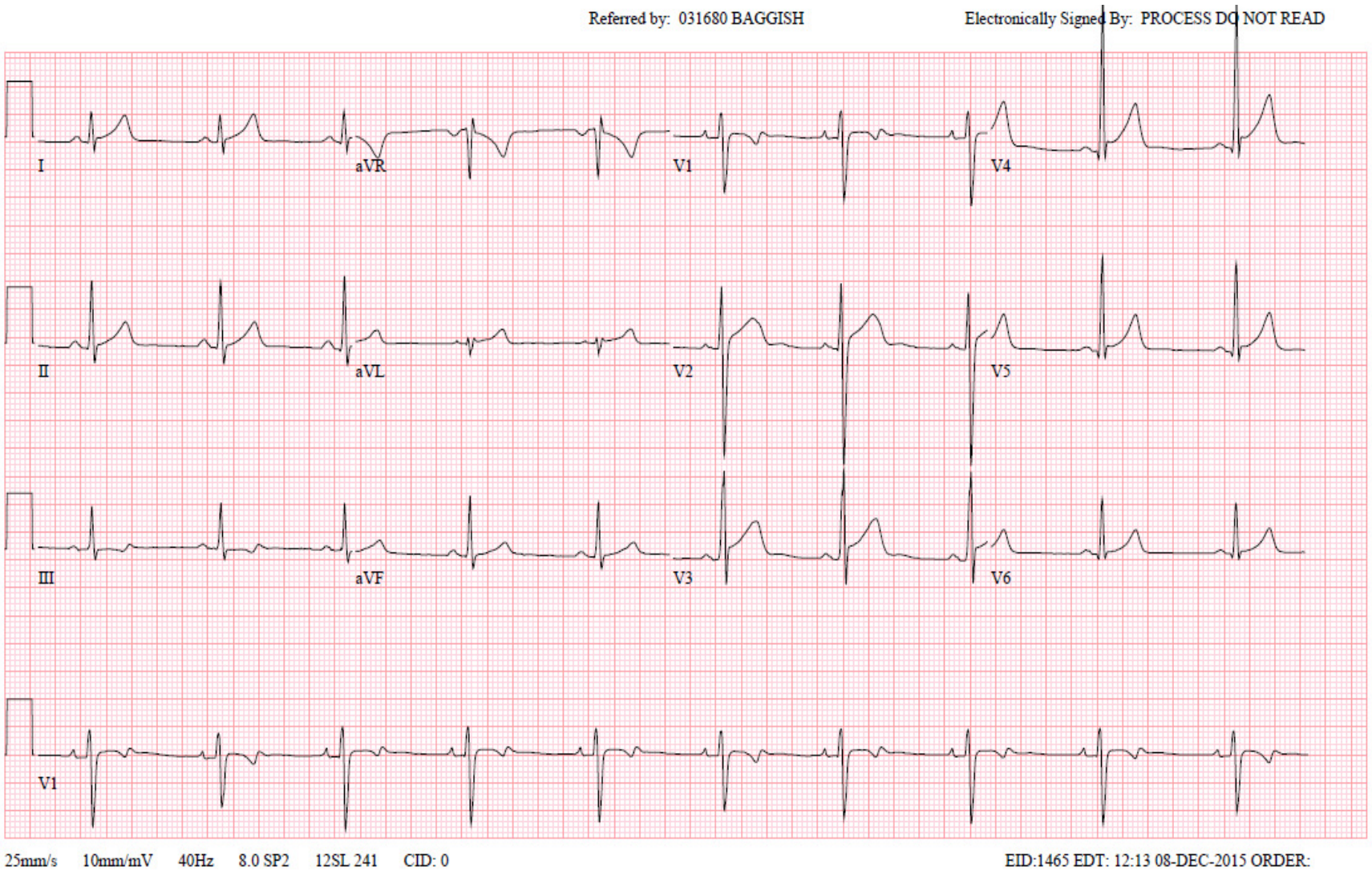
18 y.o. Black Male Lacrosse Player



ECG#4

Vent. rate
PR interval
QRS duration
QT/QTc
P-R-T axes

26 y.o. White Male Hockey Player



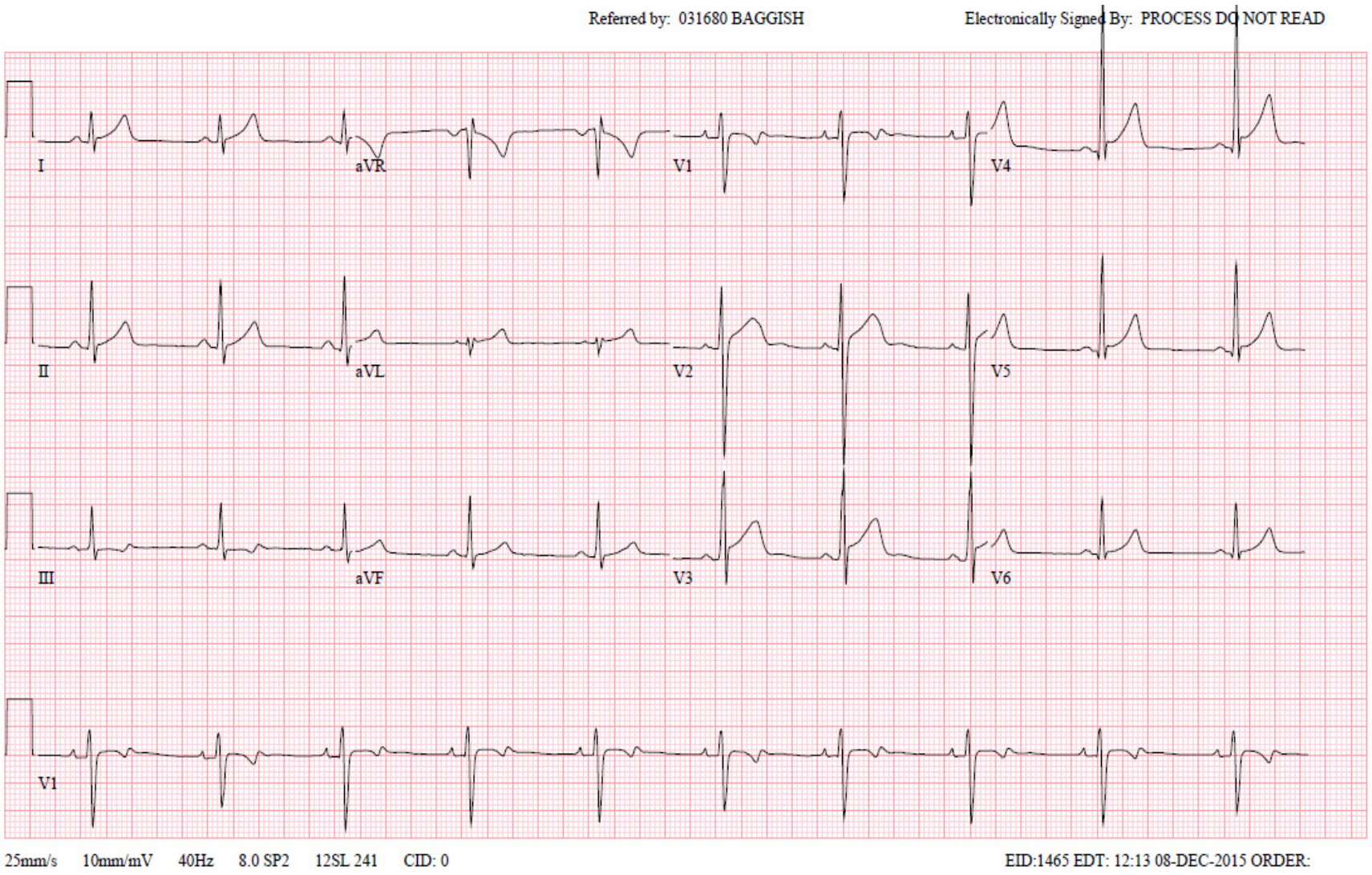
ARS ECG #4:

Audience Response

ECG#4

Vent. rate
PR interval
QRS duration
QT/QTc
P-R-T axes

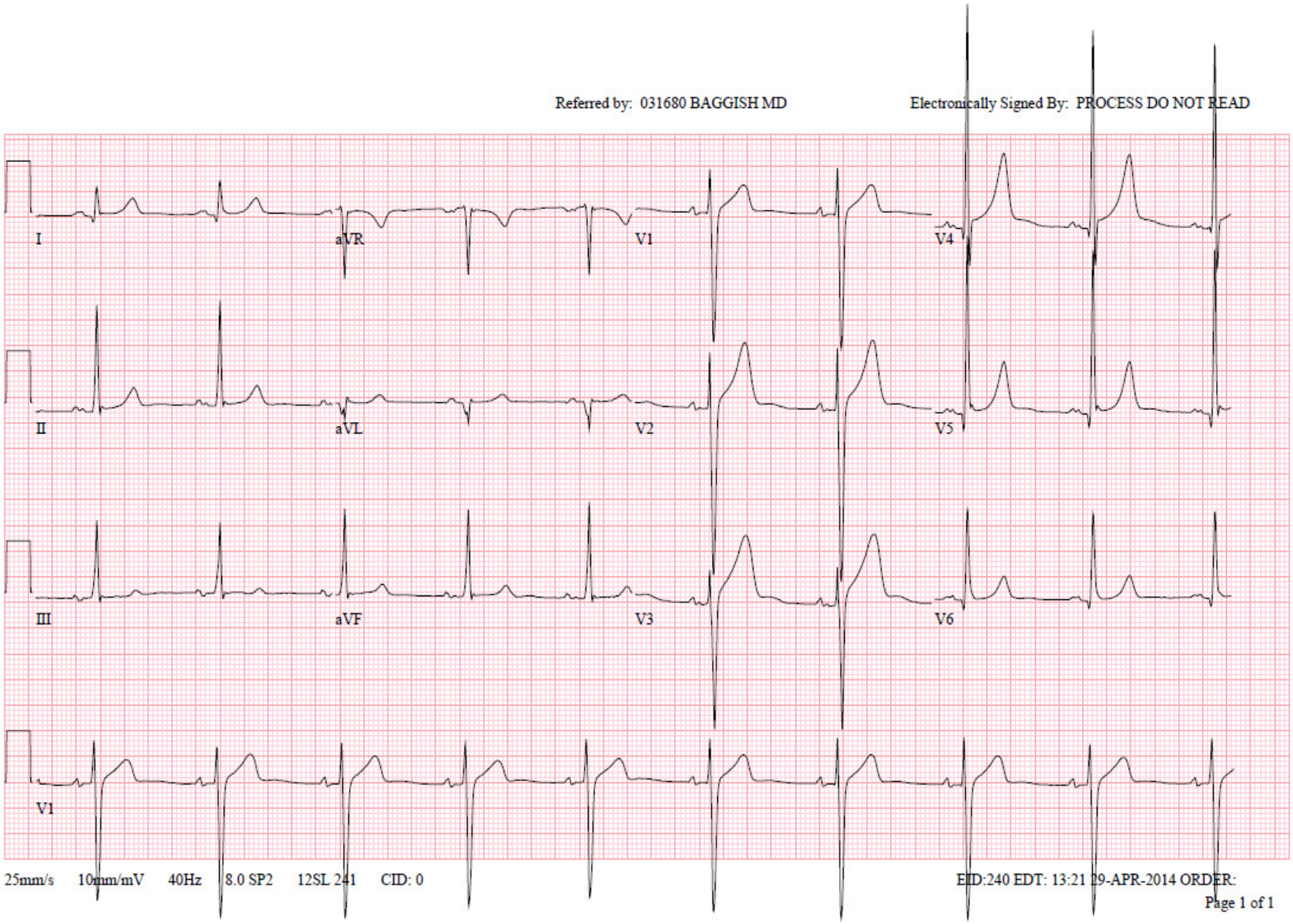
26 y.o. White Male Hockey Player



ECG#5

Vent. rate	58	BPM
PR interval	158	ms
QRS duration	104	ms
QT/QTc	442/433	ms
P-R-T axes	30 74	37

19 y.o. White Male Rower



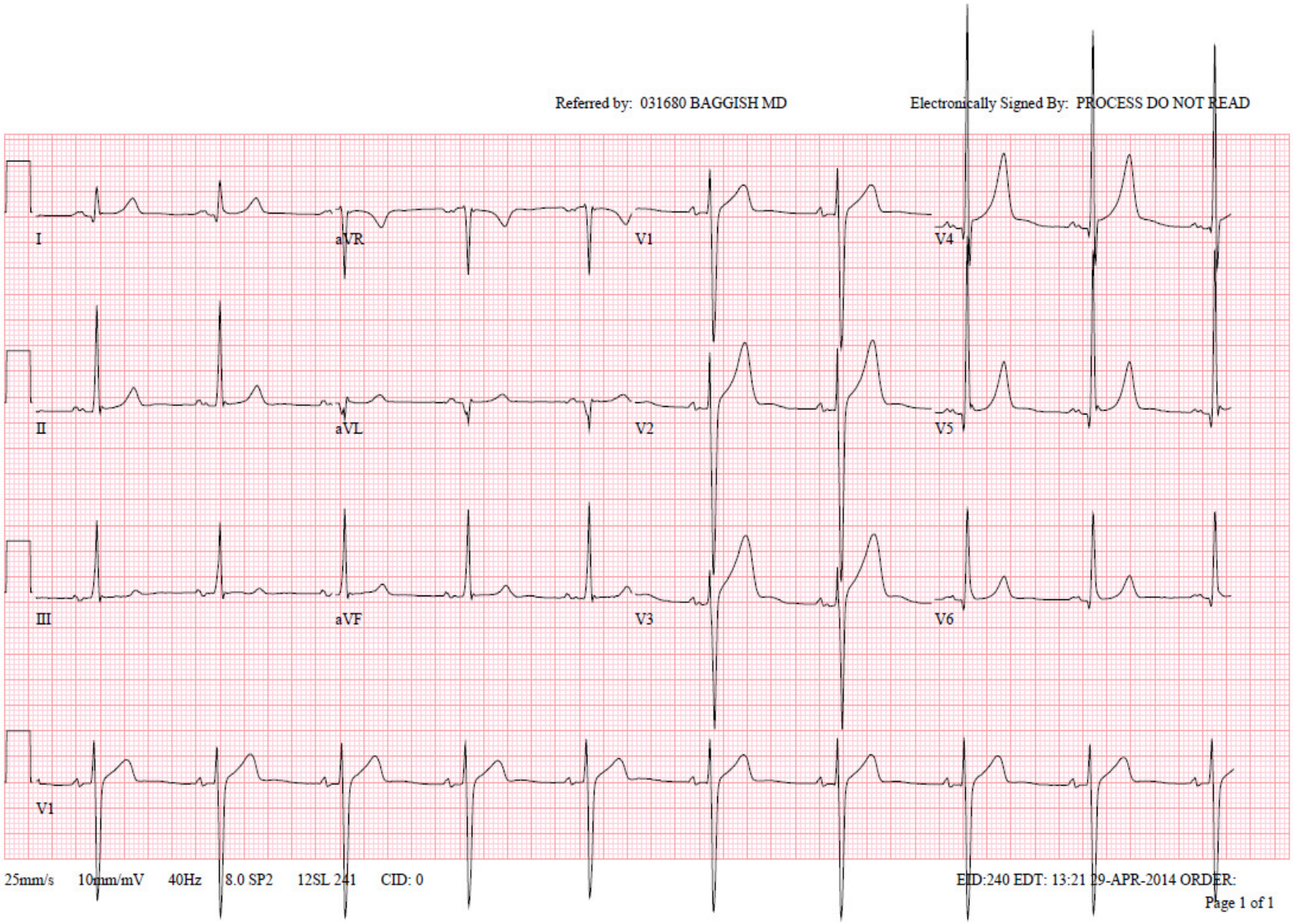
ARS ECG #5:

Audience Response

ECG#5

Vent. rate	58	BPM
PR interval	158	ms
QRS duration	104	ms
QT/QTc	442/433	ms
P-R-T axes	30 74	37

19 y.o. White Male Rower



ECG#6

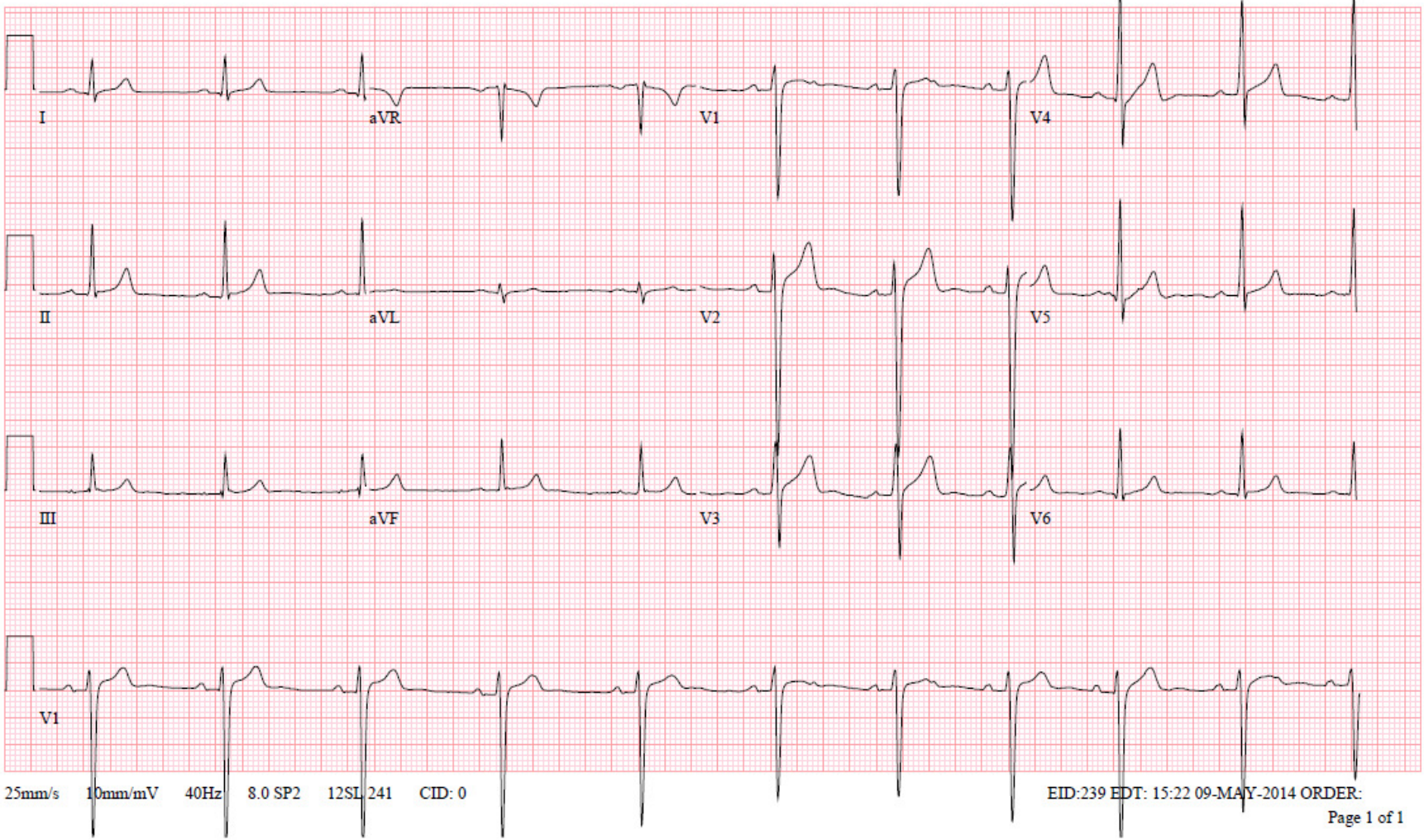
18 y.o. White Male Hurdeler

ID:005413558

Vent. rate	62	BPM
PR interval	174	ms
QRS duration	102	ms
QT/QTc	382/387	ms
P-R-T axes	30 67	51

Referred by: 031680 BAGGISH MD

Electronically Signed By: PROCESS DO NOT READ



25mm/s 10mm/mV 40Hz 8.0 SP2 12SL 241 CID: 0

EID:239 EDT: 15:22 09-MAY-2014 ORDER:

ARS ECG #6:

Audience Response

ECG#6

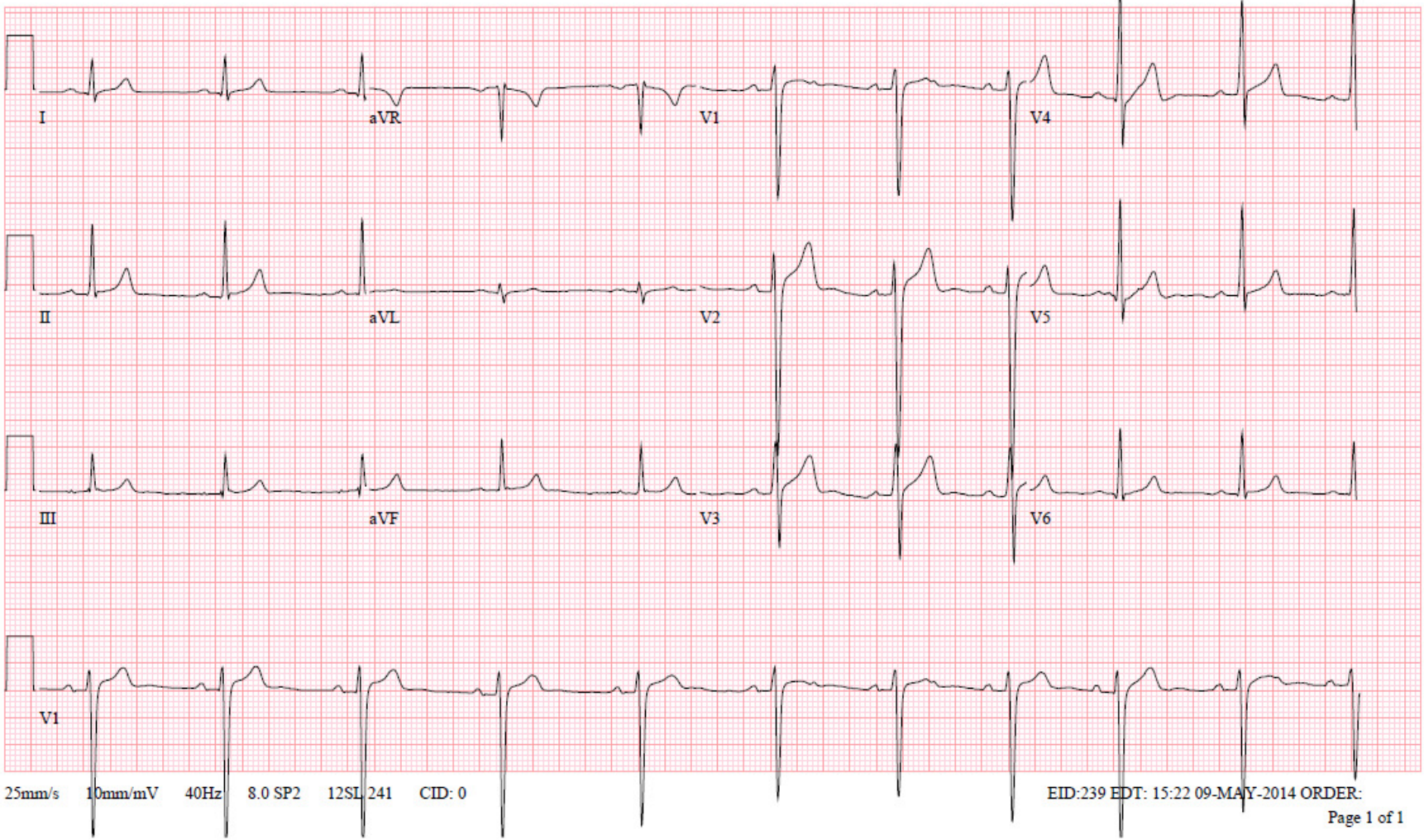
18 y.o. White Male Hurdeler

ID:005413558

Vent. rate	62	BPM
PR interval	174	ms
QRS duration	102	ms
QT/QTc	382/387	ms
P-R-T axes	30 67	51

Referred by: 031680 BAGGISH MD

Electronically Signed By: PROCESS DO NOT READ



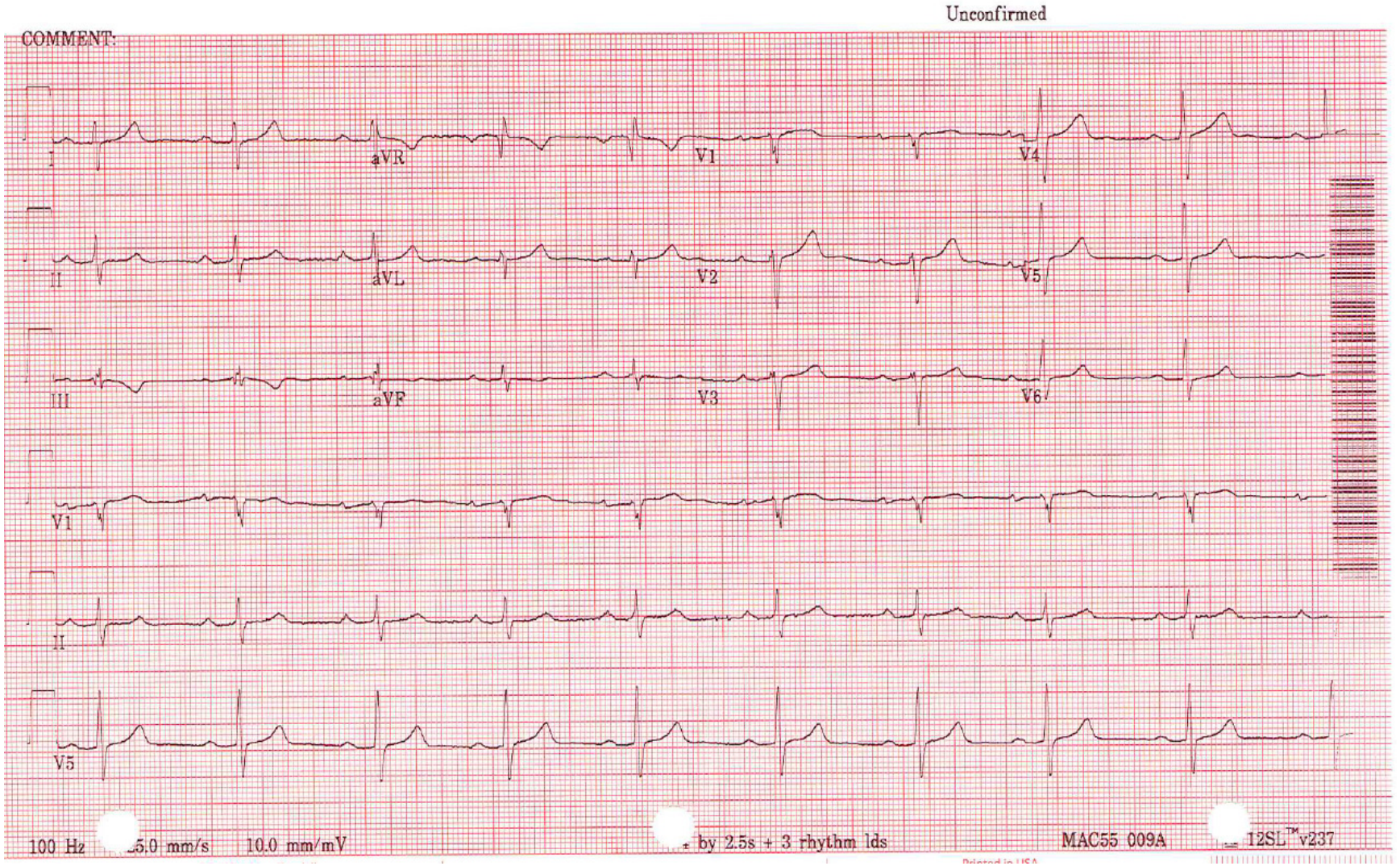
25mm/s 10mm/mV 40Hz 8.0 SP2 12SL 241 CID: 0

EID:239 EDT: 15:22 09-MAY-2014 ORDER:

ECG#7

Vent. rate	57 bpm
PR interval	244 ms
QRS duration	102 ms
QT/QTc	446/434 ms
P-R-T axes	36 117 -6

31 y.o. White Male Marathoner



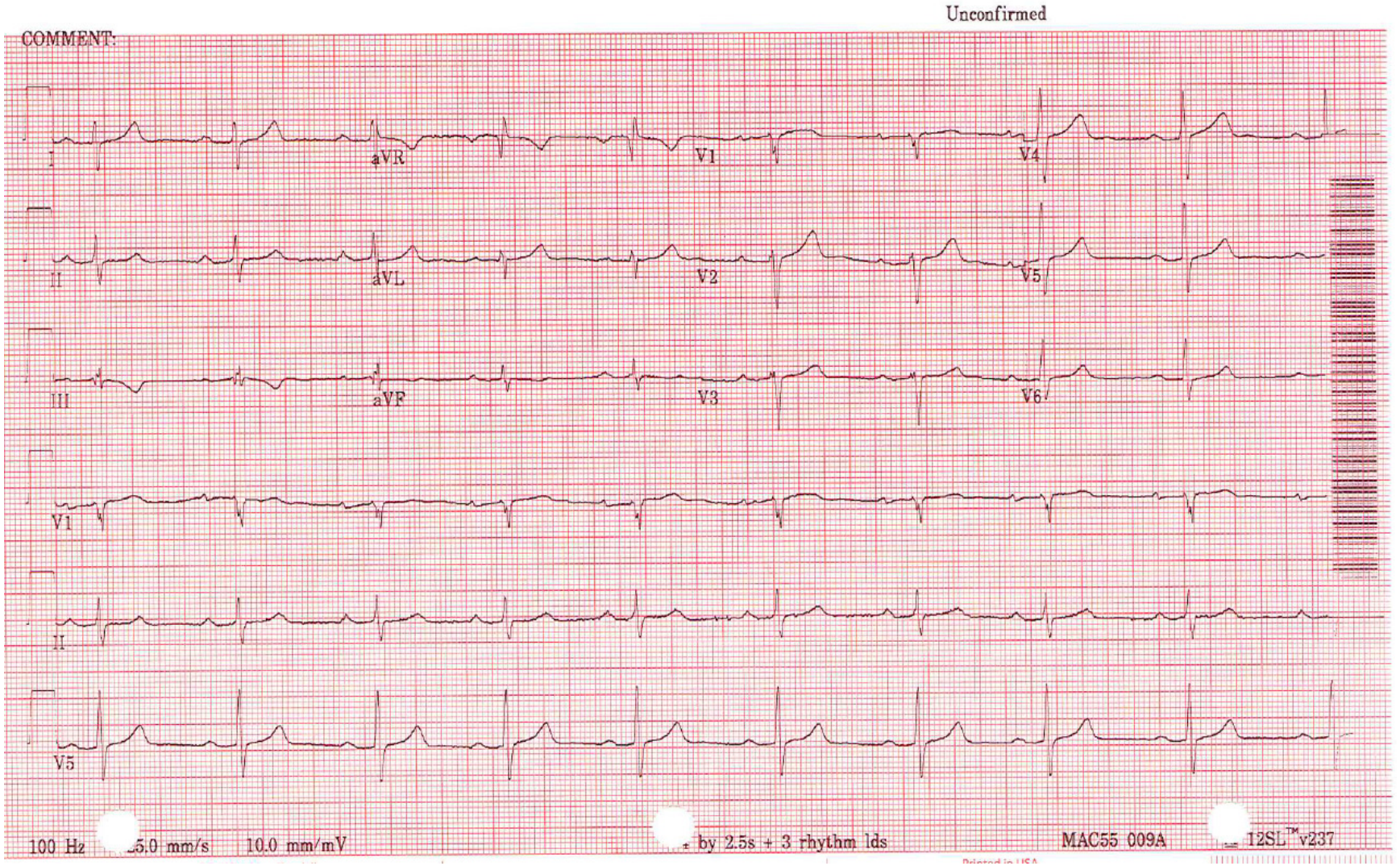
ARS ECG #7:

Audience Response

ECG#7

Vent. rate	57 bpm
PR interval	244 ms
QRS duration	102 ms
QT/QTc	446/434 ms
P-R-T axes	36 117 -6

31 y.o. White Male Marathoner

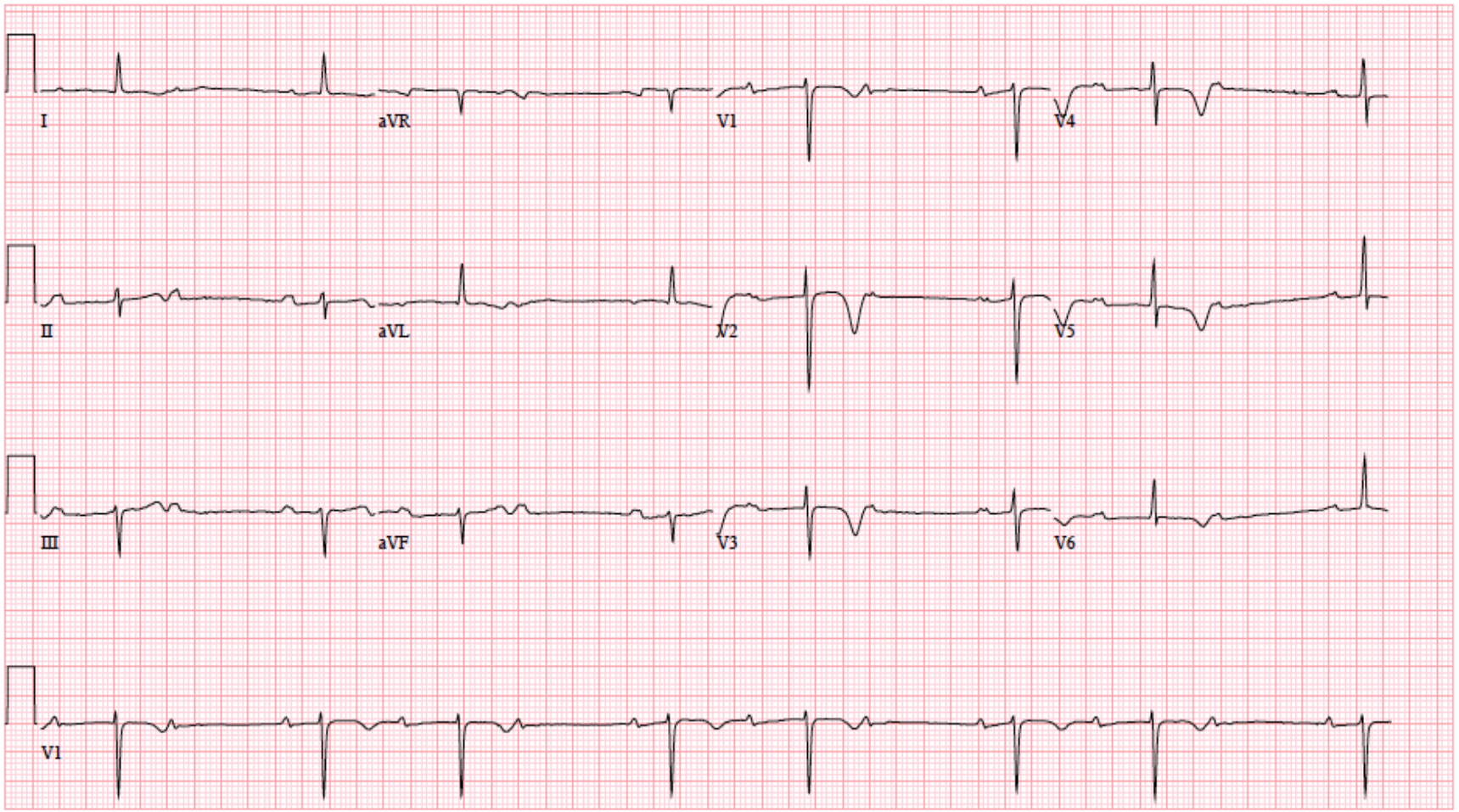


ECG#8

ID:002087600

Vent. rate	45	BPM
PR interval	*	ms
QRS duration	80	ms
QT/QTc	480/415	ms
P-R-T axes	74 -37	117

21 y.o. Black Male Soccer Player



25mm/s 10mm/mV 40Hz 8.0 SP2 12SL 241 CID: 0 EID: EDT: ORDER: ACCOUNT: 3118612622

ARS ECG #8:

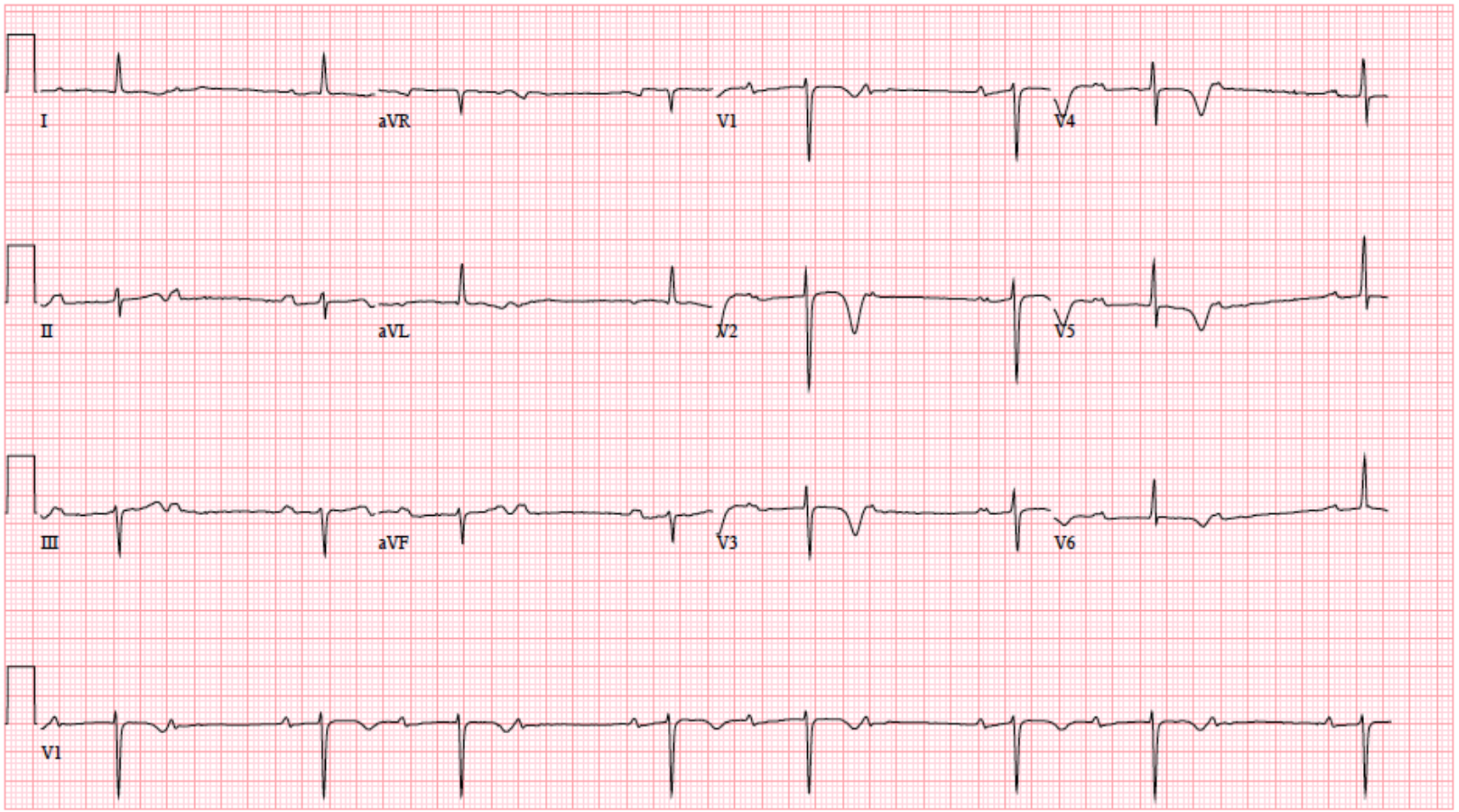
Audience Response

ECG#8

ID:002087600

Vent. rate	45	BPM
PR interval	*	ms
QRS duration	80	ms
QT/QTc	480/415	ms
P-R-T axes	74 -37	117

21 y.o. Black Male Soccer Player

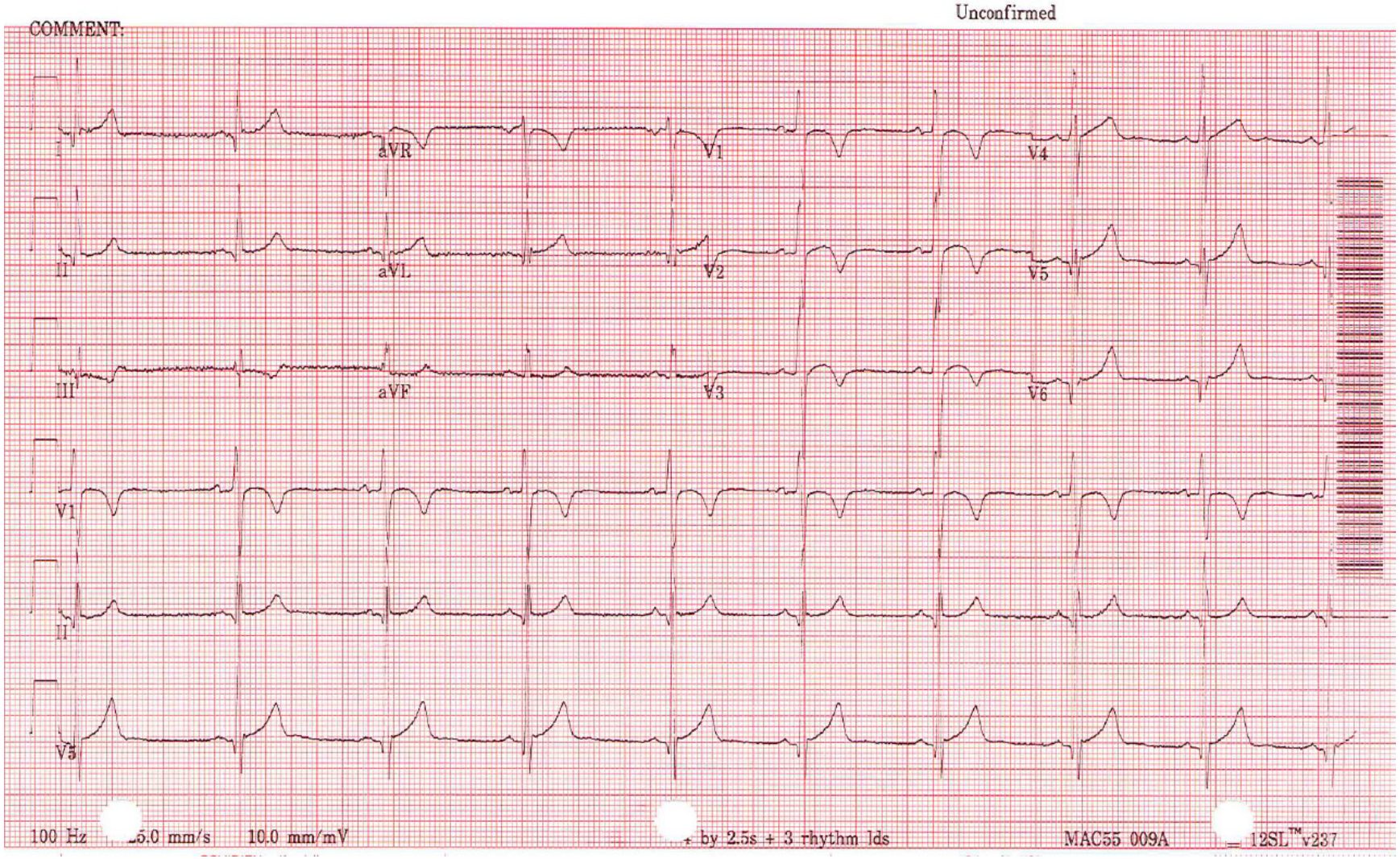


25mm/s 10mm/mV 40Hz 8.0 SP2 12SL 241 CID: 0 EID: EDT: ORDER: ACCOUNT: 3118612622

ECG#9

Vent. rate	56 bpm
PR interval	144 ms
QRS duration	98 ms
QT/QTc	430/414 ms
P-R-T axes	51 35 15

22 y.o. Black Male Soccer Player



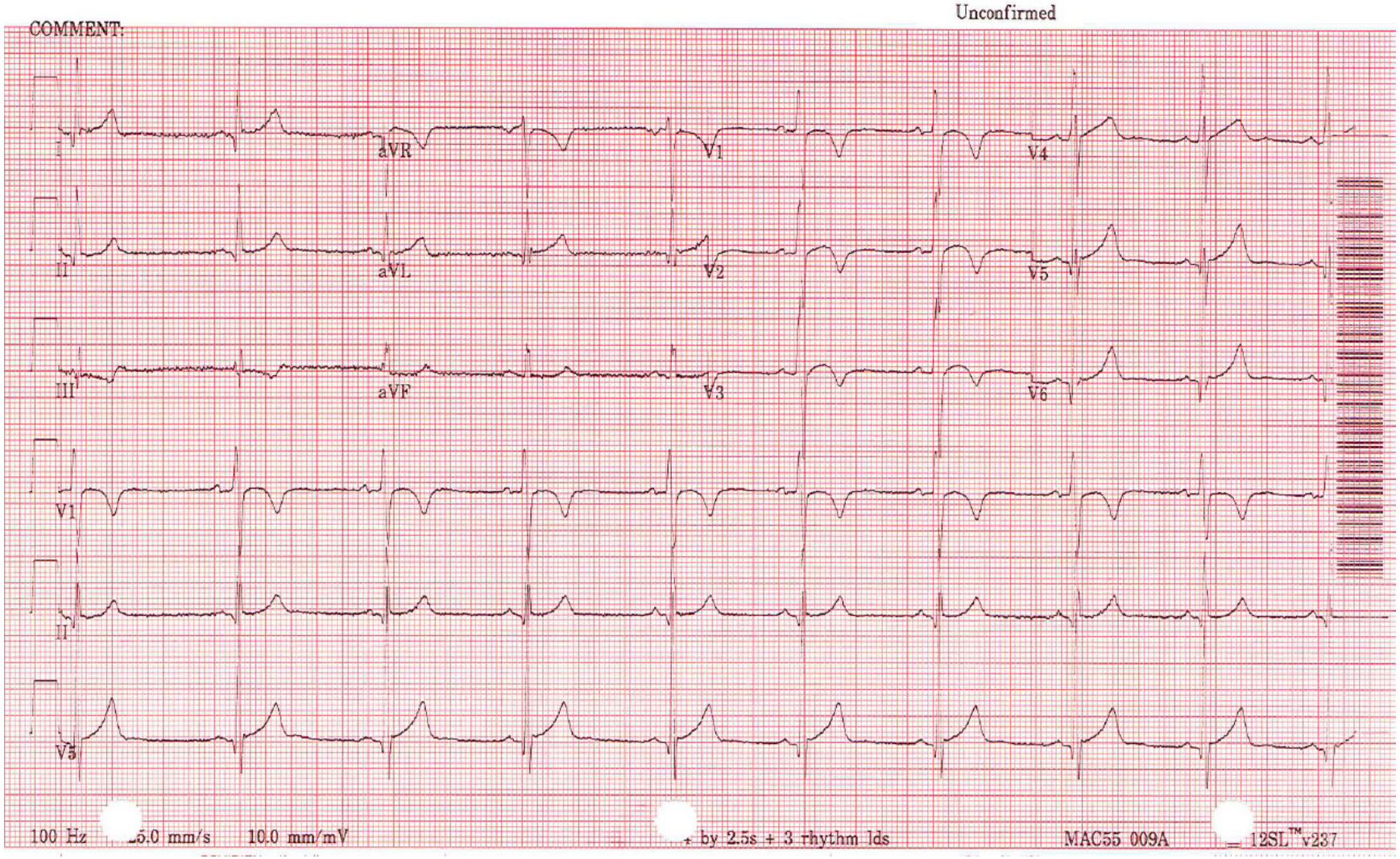
ARS ECG #9:

Audience Response

ECG#9

Vent. rate	56 bpm
PR interval	144 ms
QRS duration	98 ms
QT/QTc	430/414 ms
P-R-T axes	51 35 15

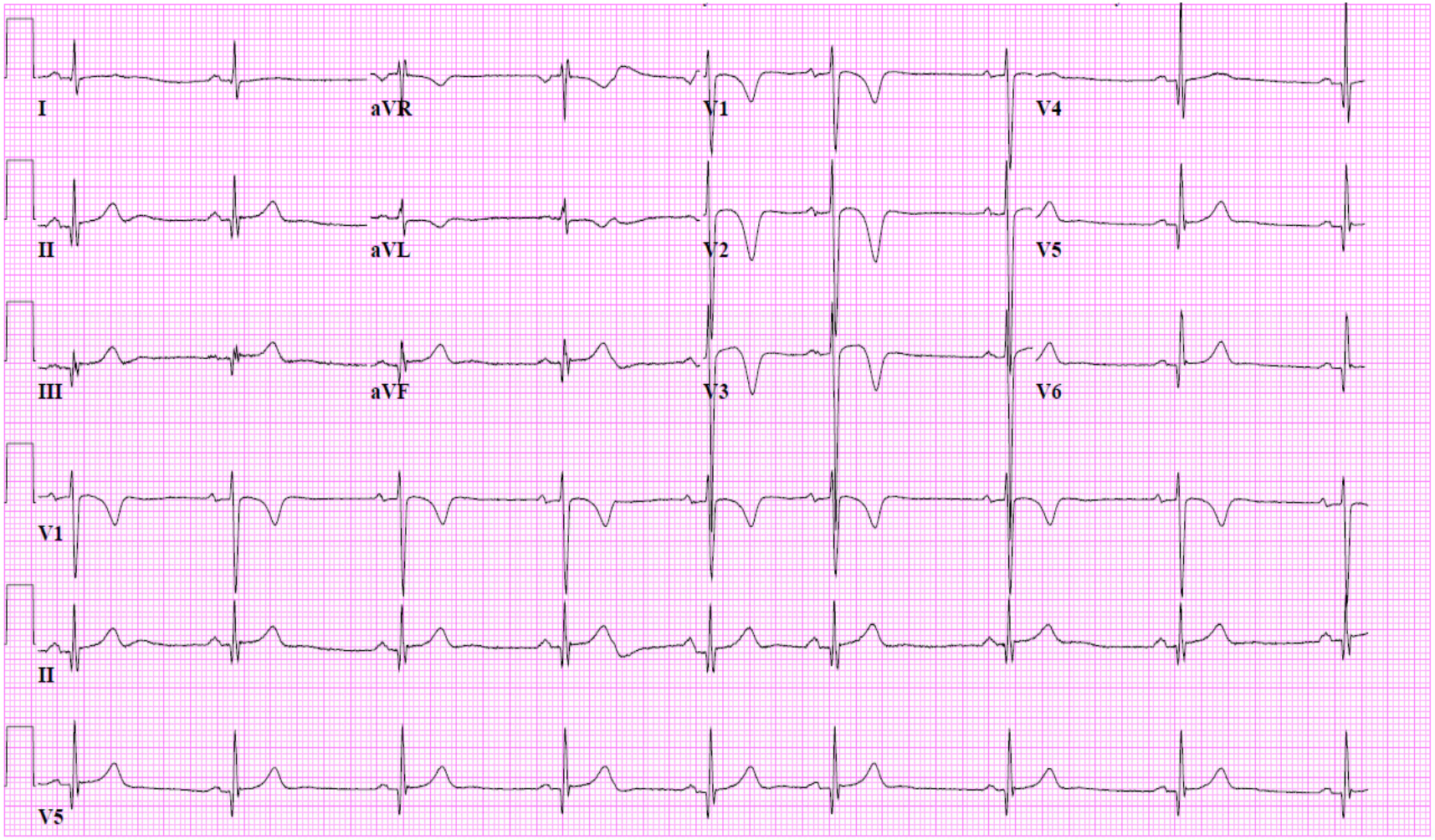
22 y.o. Black Male Soccer Player



ECG#10

Vent. rate	50	BPM
PR interval	170	ms
QRS duration	90	ms
QT/QTc	442/402	ms
P-R-T axes	45 31	81

22 y.o. White Female Soccer Player



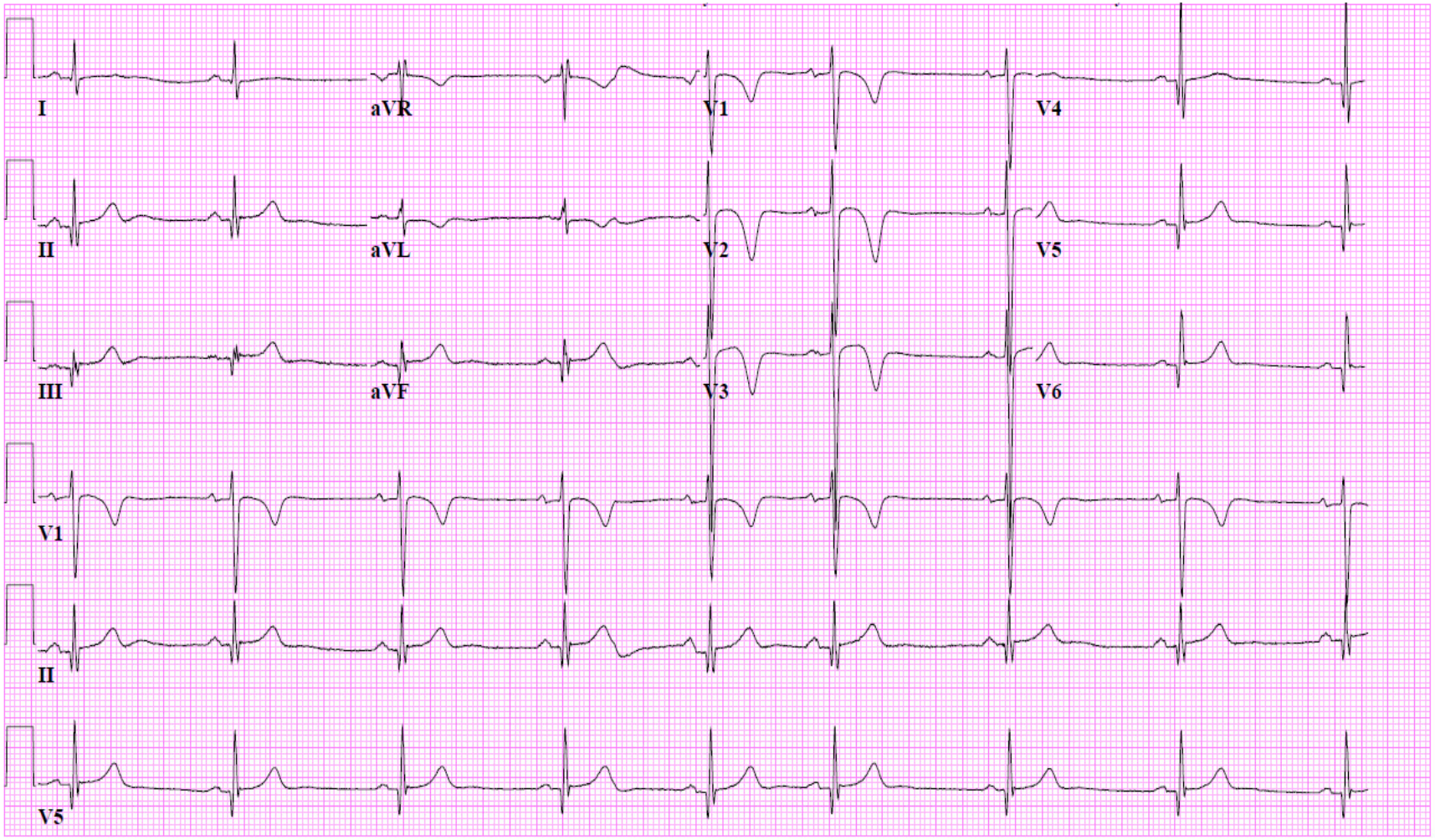
ARS ECG #10:

Audience Response

ECG#10

Vent. rate	50	BPM
PR interval	170	ms
QRS duration	90	ms
QT/QTc	442/402	ms
P-R-T axes	45 31	81

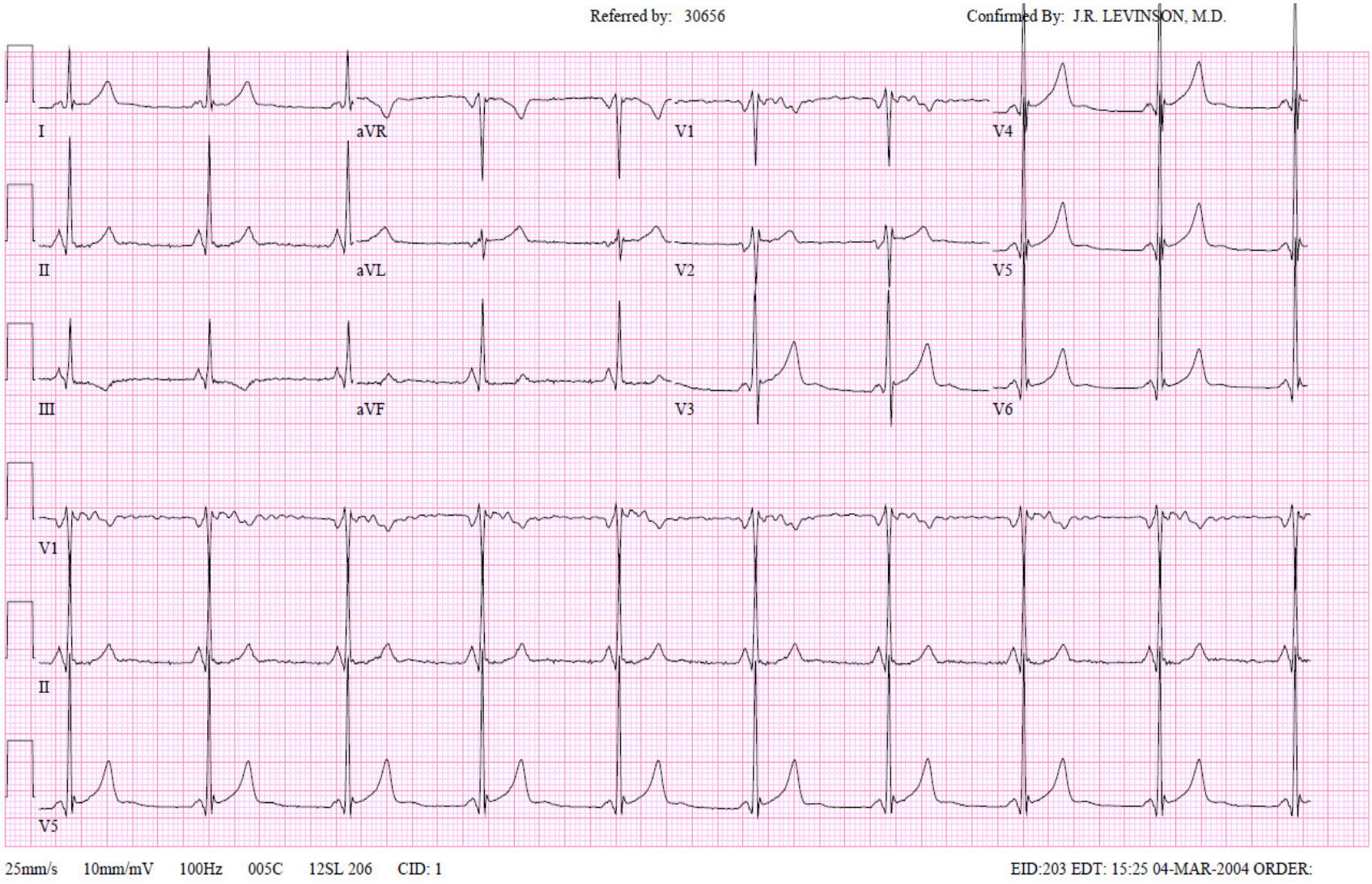
22 y.o. White Female Soccer Player



ECG#11

Vent. rate	56	BPM
PR interval	100	ms
QRS duration	112	ms
QT/QTc	436/421	ms
P-R-T axes	240 60	-28

19 y.o. White Female Rower



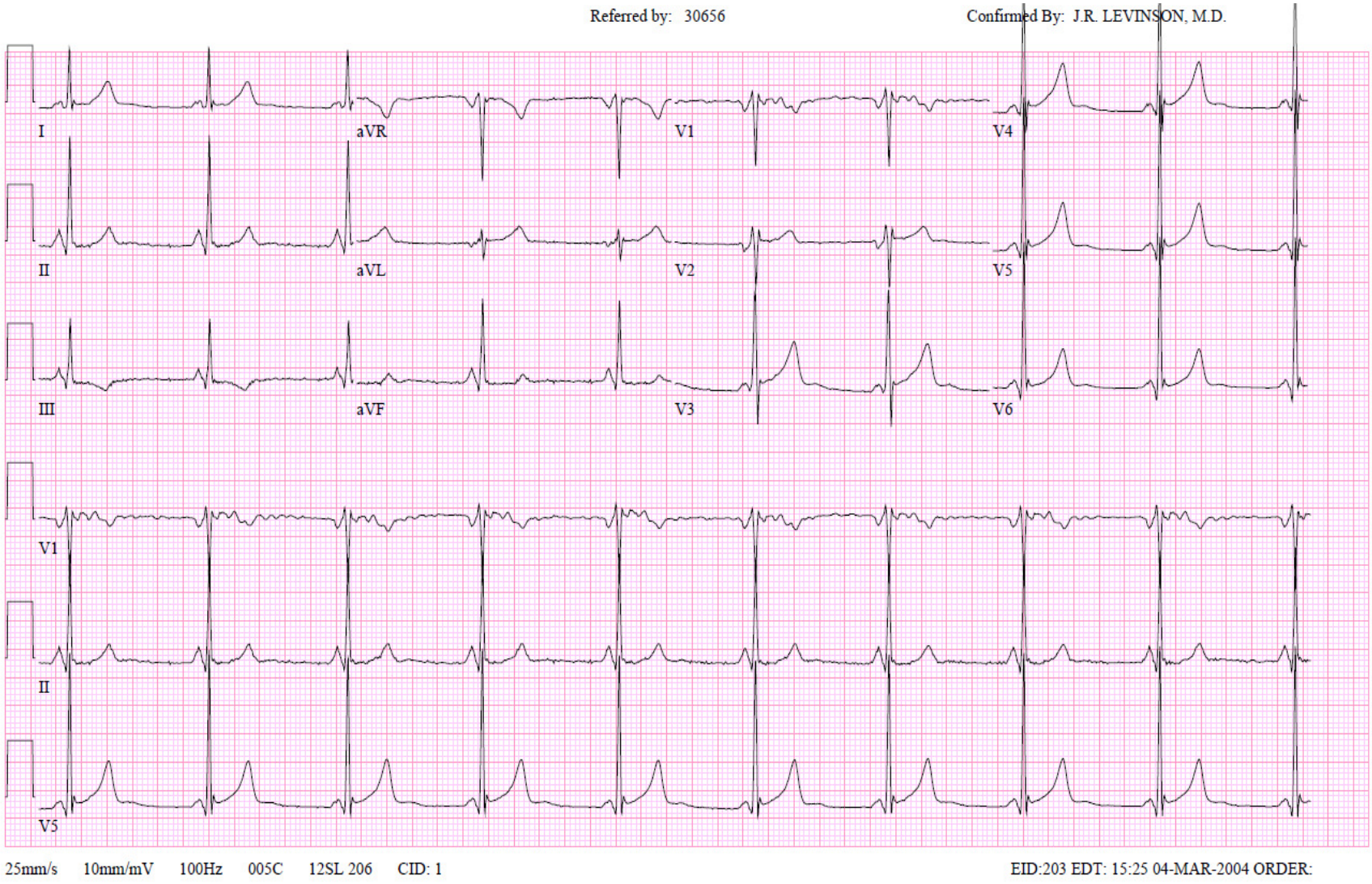
ARS ECG #11:

Audience Response

ECG#11

Vent. rate	56	BPM
PR interval	100	ms
QRS duration	112	ms
QT/QTc	436/421	ms
P-R-T axes	240 60	-28

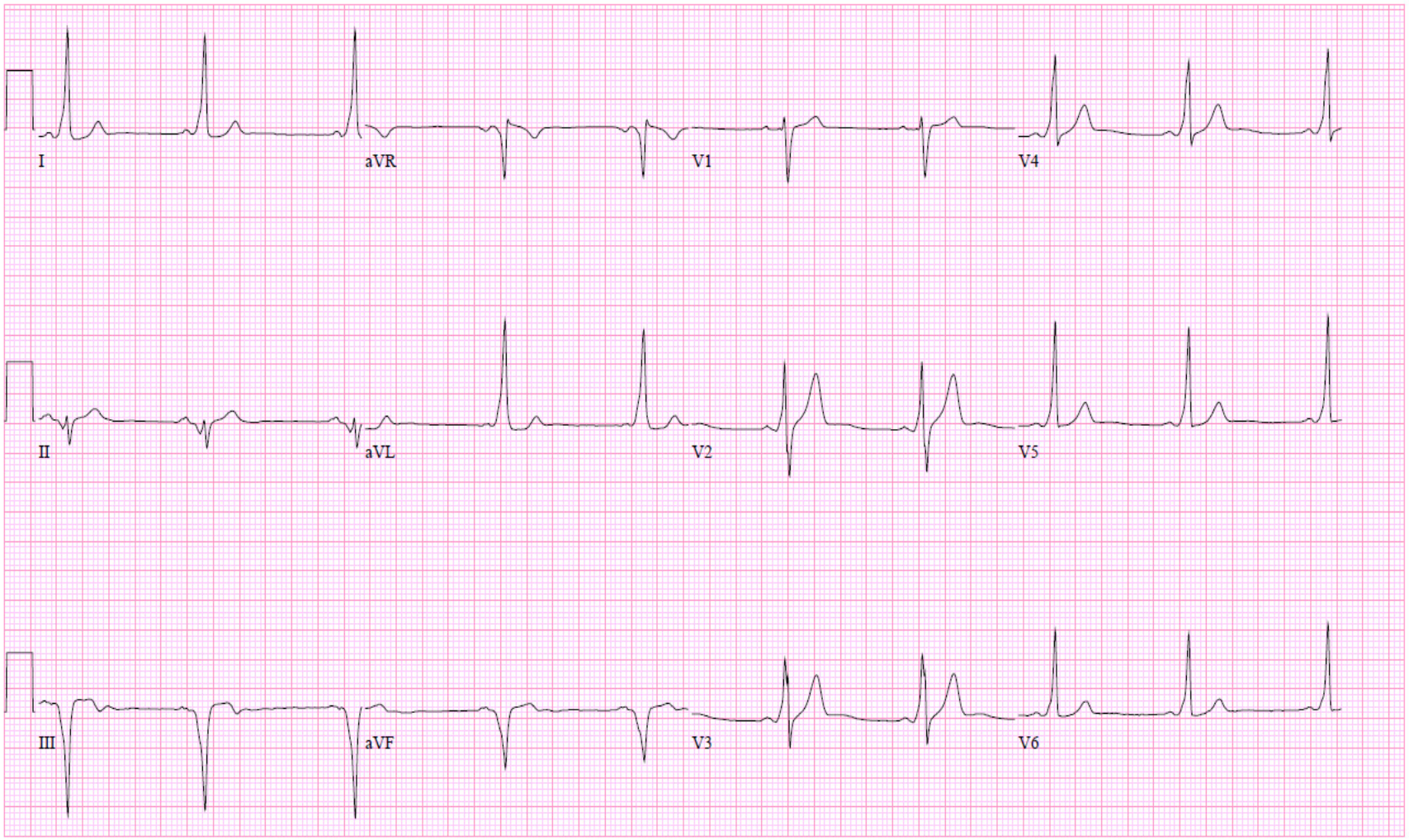
19 y.o. White Female Rower



ECG#12

Vent. rate	55	BPM
PR interval	116	ms
QRS duration	132	ms
QT/QTc	400/382	ms
P-R-T axes	48 -36	19

19 y.o. White Male Distance Runner



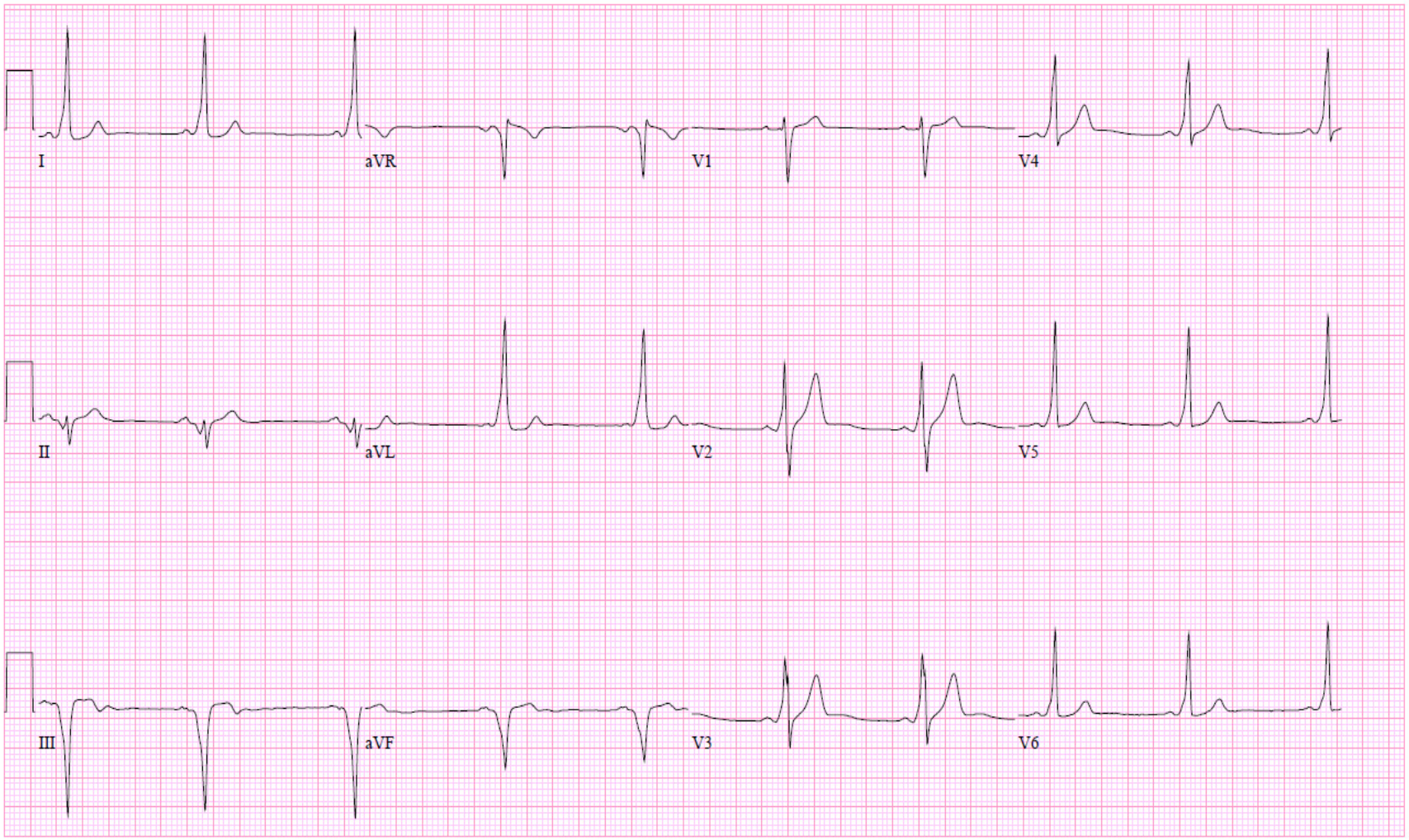
ARS ECG #12:

Audience Response

ECG#12

Vent. rate	55	BPM
PR interval	116	ms
QRS duration	132	ms
QT/QTc	400/382	ms
P-R-T axes	48 -36	19

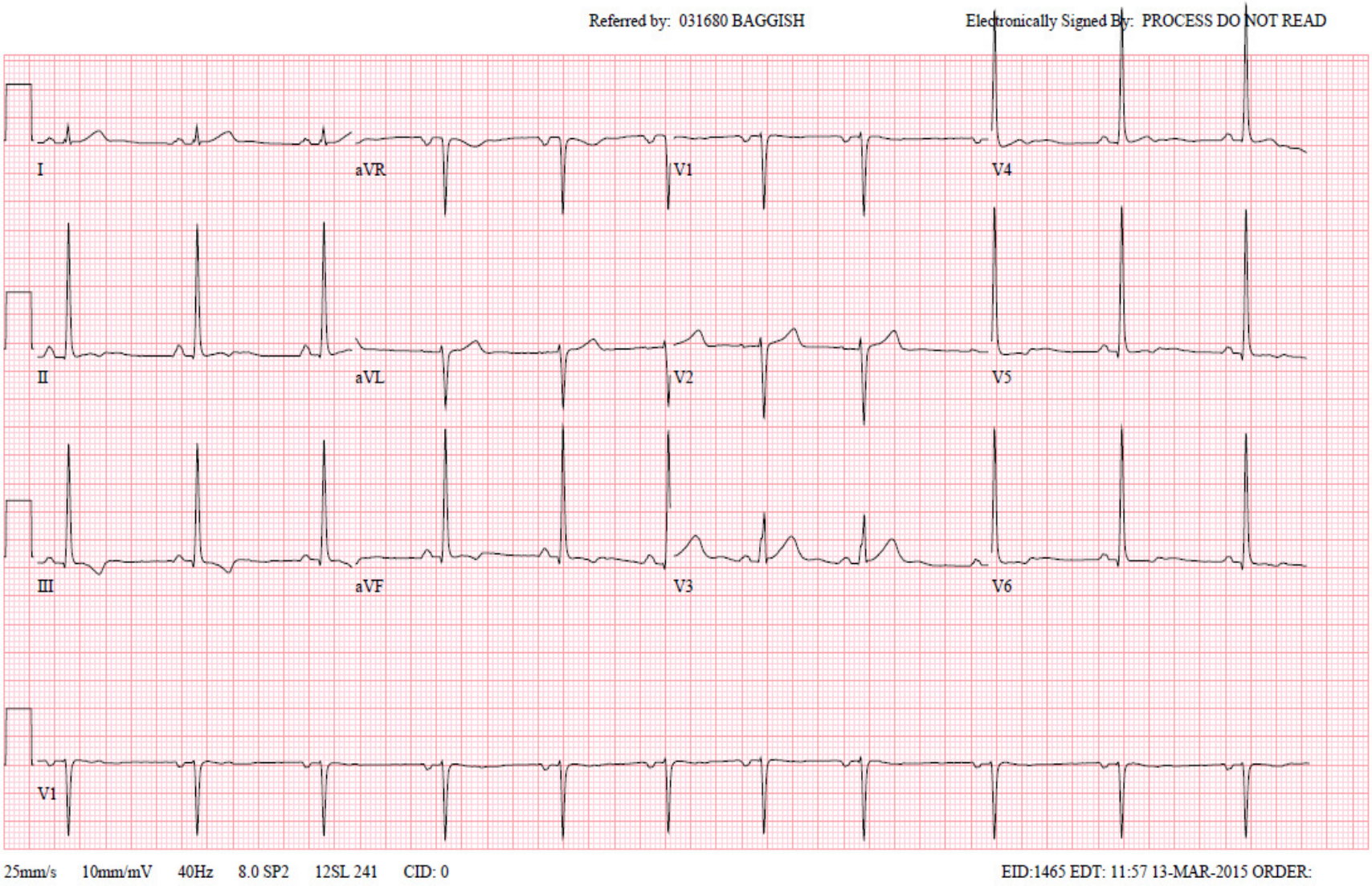
19 y.o. White Male Distance Runner



ECG#14

Vent. rate	65	BPM
PR interval	152	ms
QRS duration	88	ms
QT/QTc	370/384	ms
P-R-T axes	59 84	-3

20 y.o. White Male Football Player



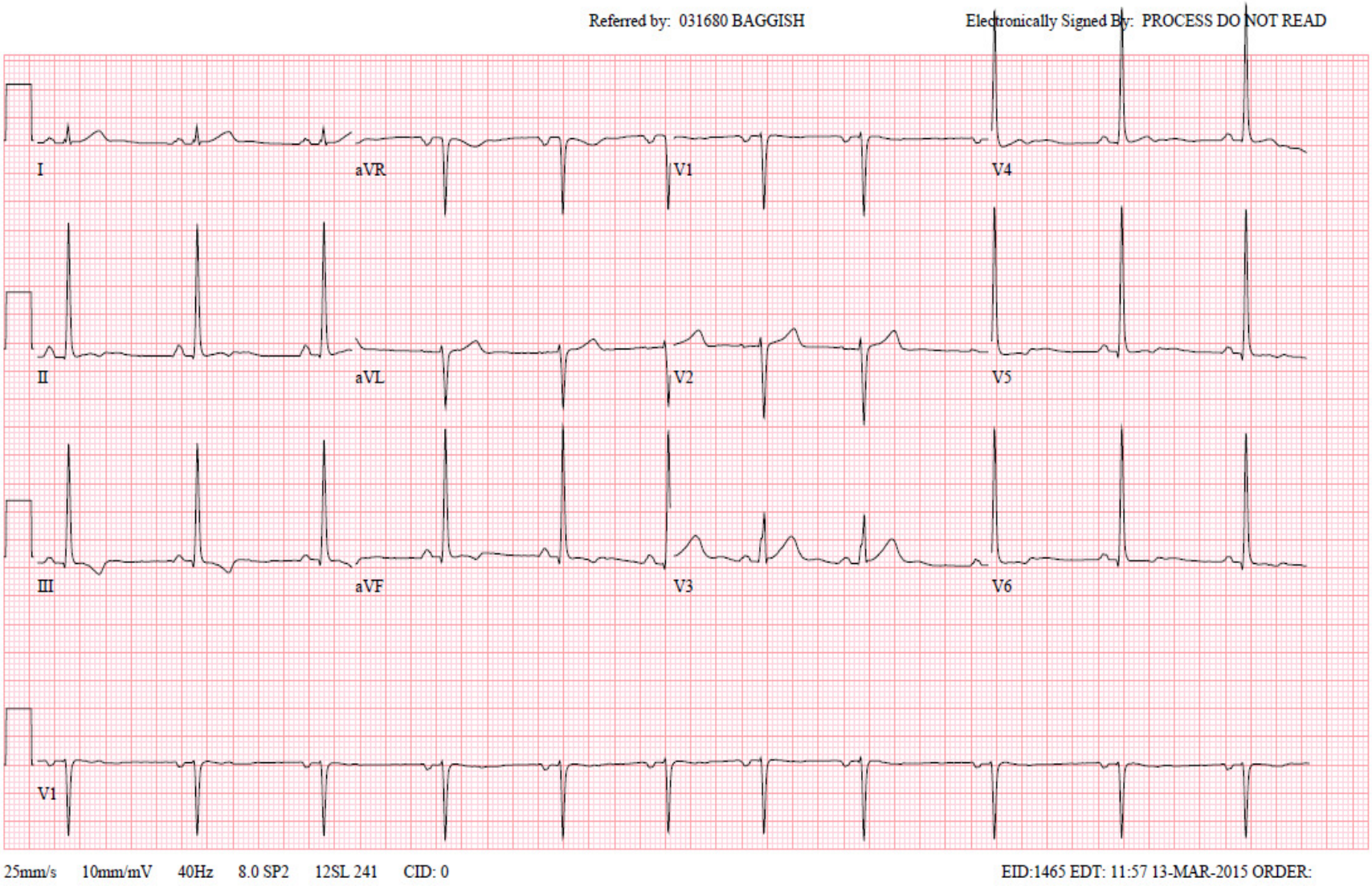
ARS ECG #13:

Audience Response

ECG#14

Vent. rate	65	BPM
PR interval	152	ms
QRS duration	88	ms
QT/QTc	370/384	ms
P-R-T axes	59 84	-3

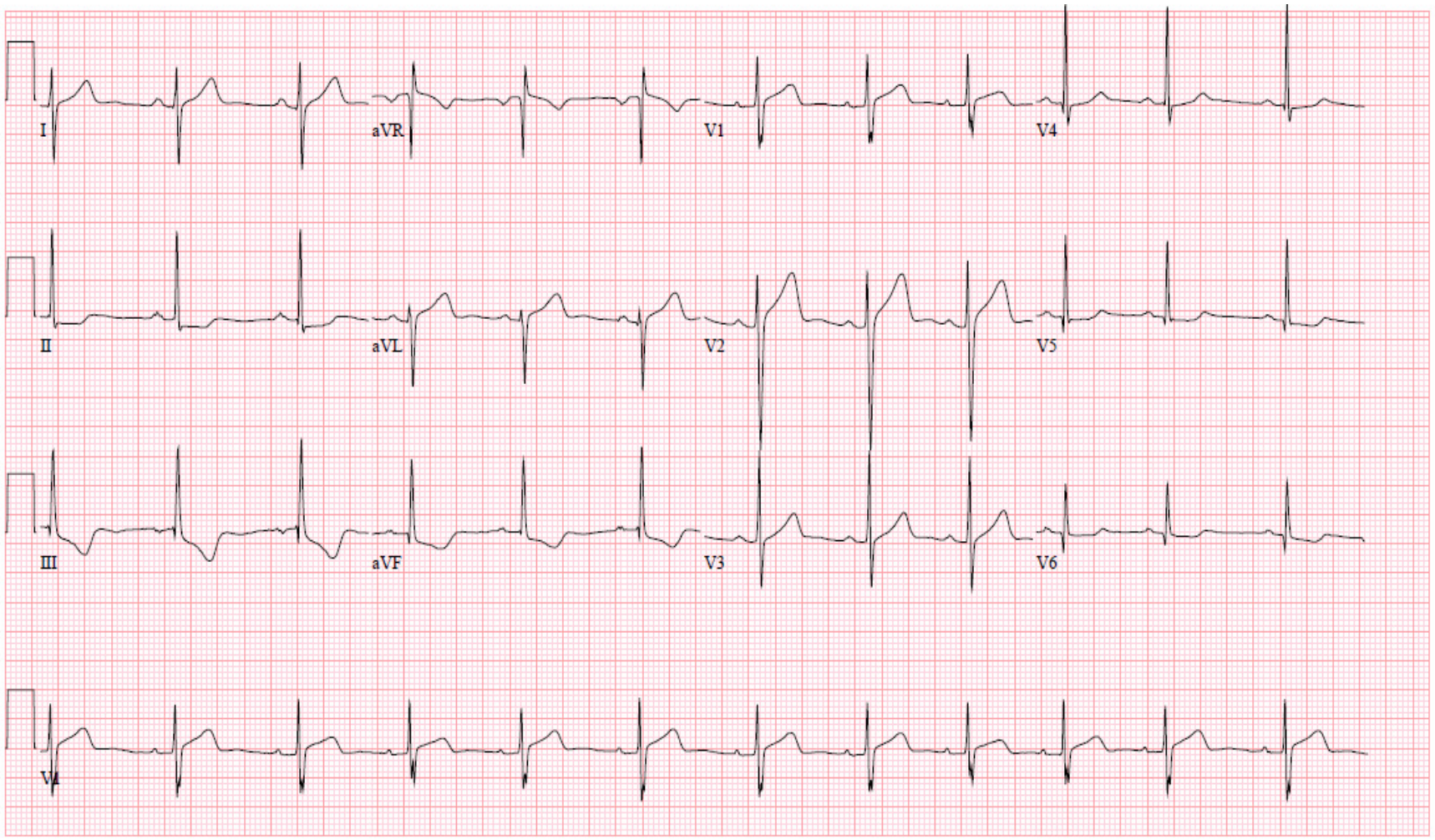
20 y.o. White Male Football Player



ECG#14

Vent. rate	71	BPM
PR interval	168	ms
QRS duration	78	ms
QT/QTc	390/423	ms
P-R-T axes	26 99	-34

20 y.o. White Female Basketball Player



25mm/s 10mm/mV 40Hz 8.0 SP2 12SL 241 CID: 0

EID:1465 EDT: 07:34 24-DEC-2014 ORDER:

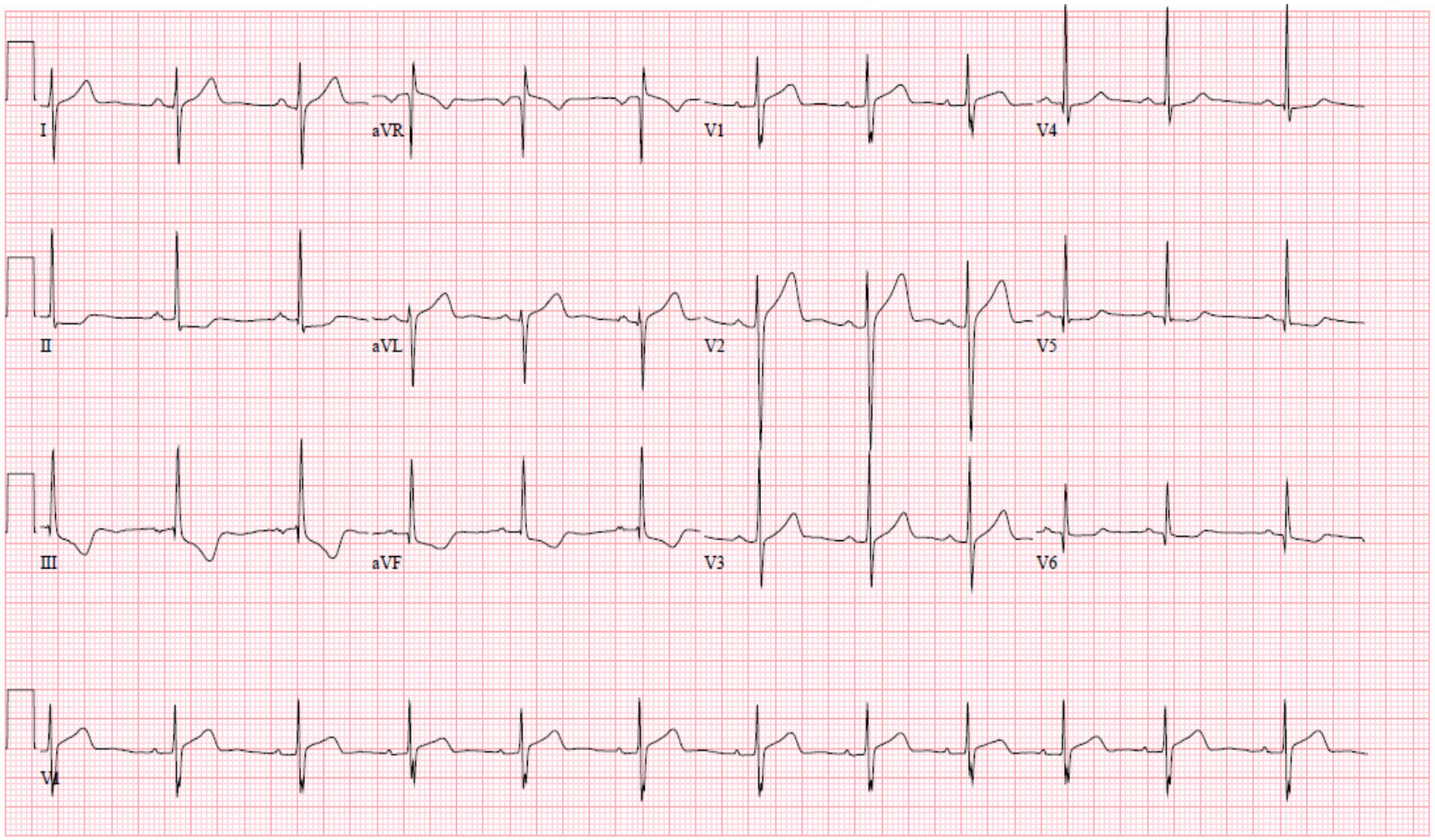
ARS ECG #14:

Audience Response

ECG#14

Vent. rate	71	BPM
PR interval	168	ms
QRS duration	78	ms
QT/QTc	390/423	ms
P-R-T axes	26 99	-34

20 y.o. White Female Basketball Player



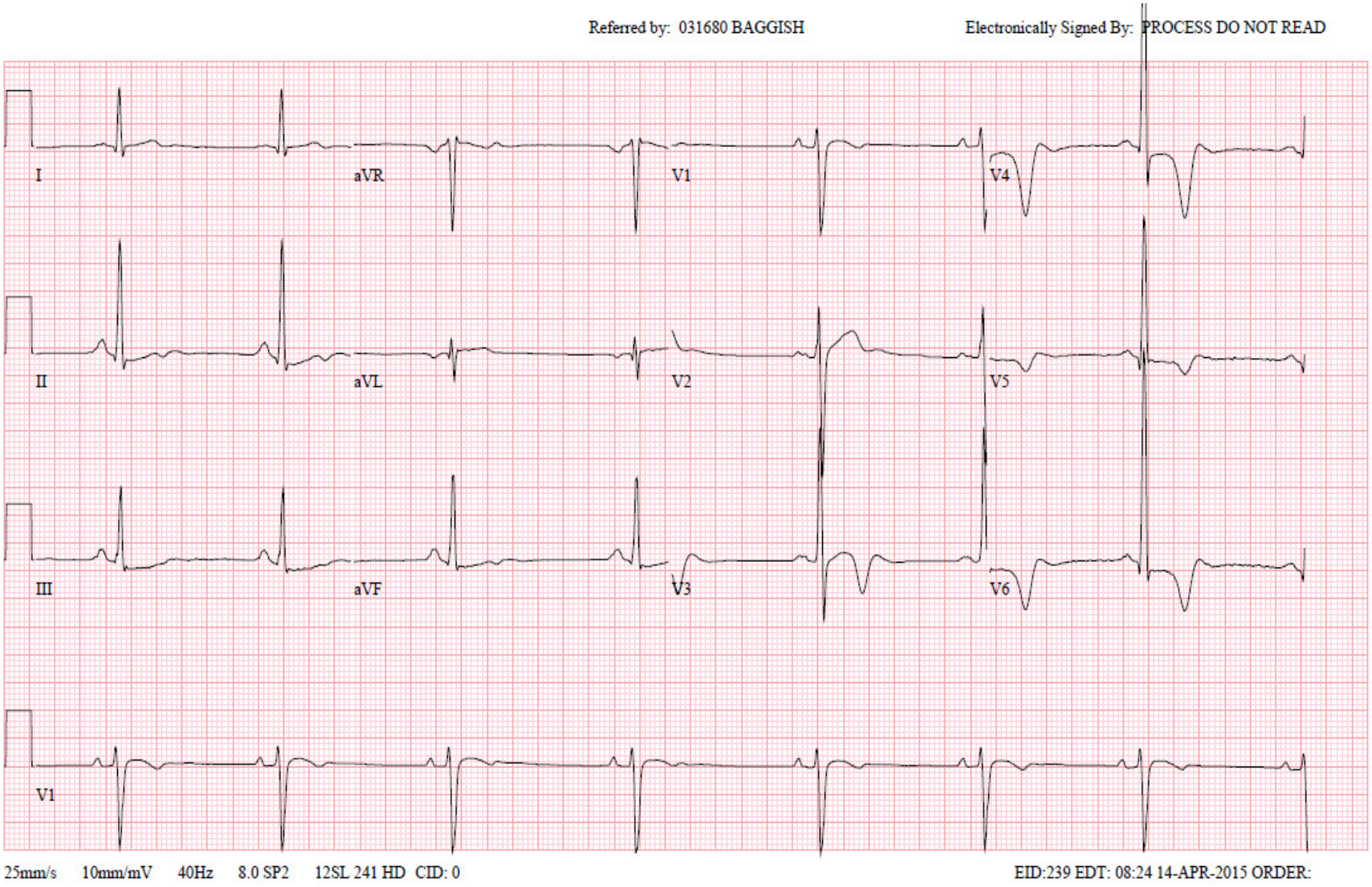
25mm/s 10mm/mV 40Hz 8.0 SP2 12SL 241 CID: 0

EID:1465 EDT: 07:34 24-DEC-2014 ORDER:

ECG#15

Vent. rate	45	BPM
PR interval	164	ms
QRS duration	110	ms
QT/QTc	478/413	ms
P-R-T axes	76 64	-10

26 y.o. White Male Triathlete



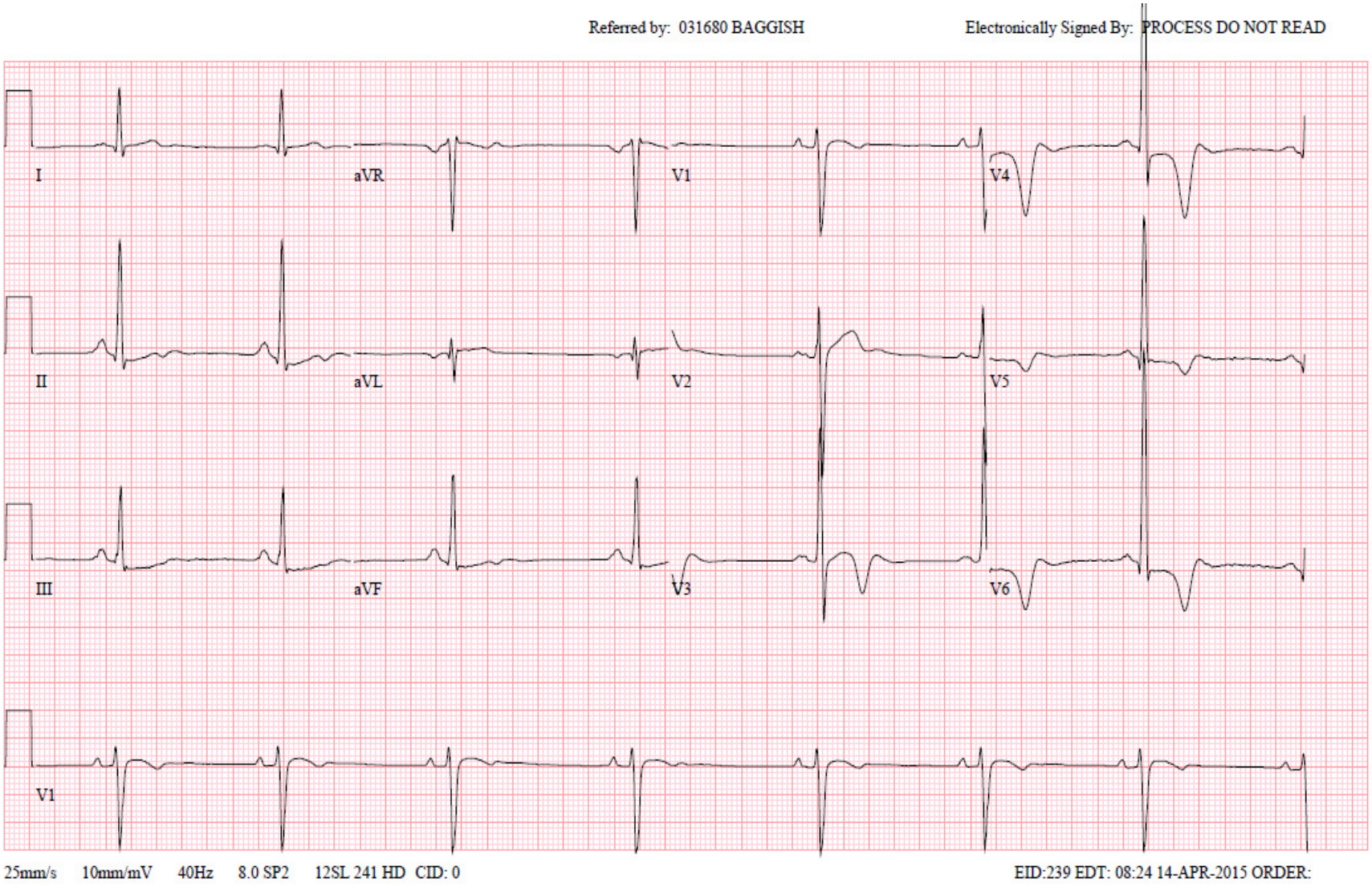
ARS ECG #15:

Audience Response

ECG#15

Vent. rate	45	BPM
PR interval	164	ms
QRS duration	110	ms
QT/QTc	478/413	ms
P-R-T axes	76 64	-10

26 y.o. White Male Triathlete



ECG#16

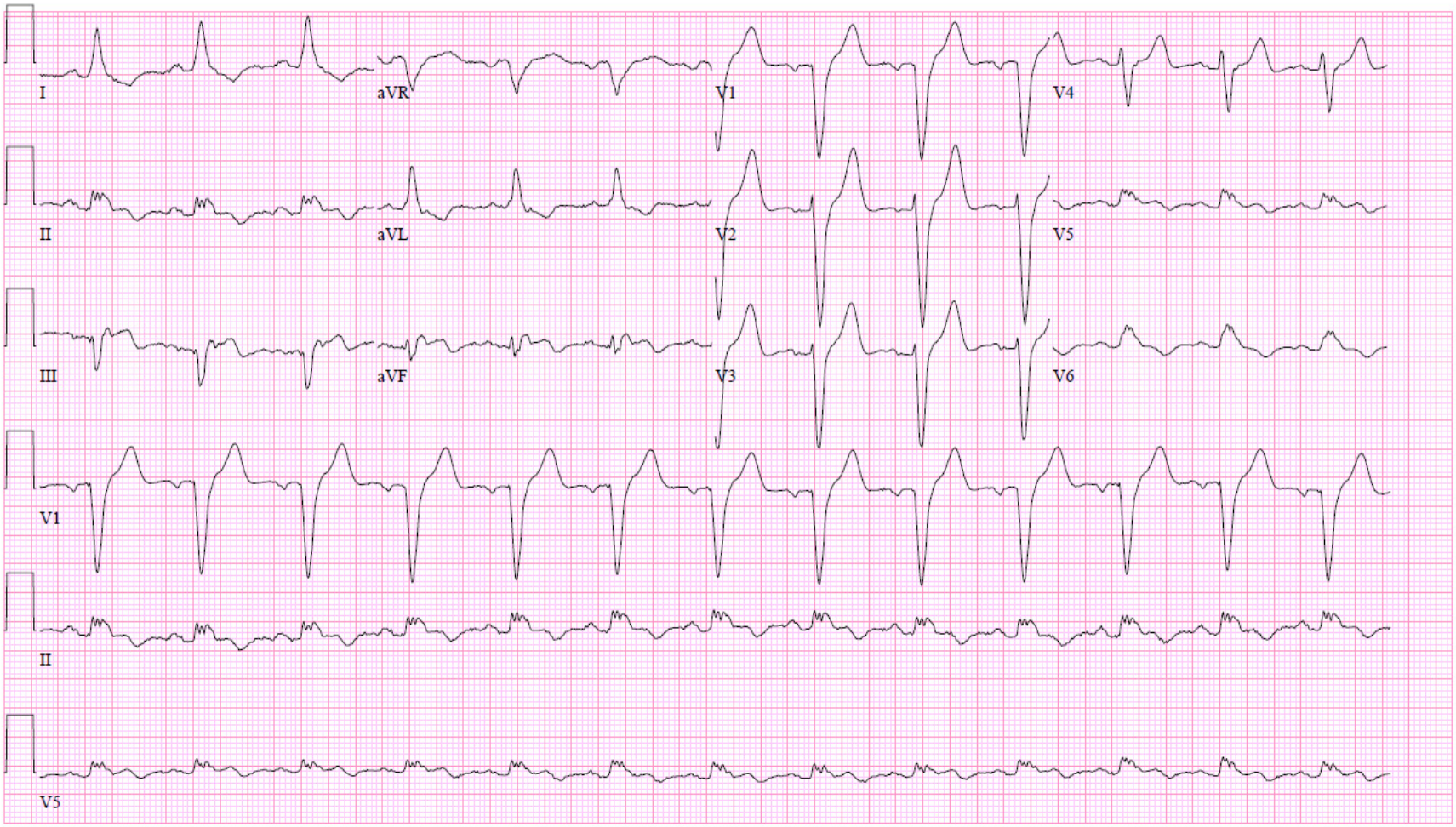
Vent. rate	79	BPM
PR interval	174	ms
QRS duration	140	ms
QT/QTc	438/502	ms
P-R-T axes	50 -9	174

21 y.o. White Male Middle Distance Runner

Technician: TN
Test ind:NOBILL

Referred by:

Confirmed By:



25mm/s 10mm/mV 40Hz 005C 12SL 233 CID: 1

EID:202 EDT: 10:45 11-JUN-2004 ORDER:

ARS ECG #16:

Audience Response

ECG#16

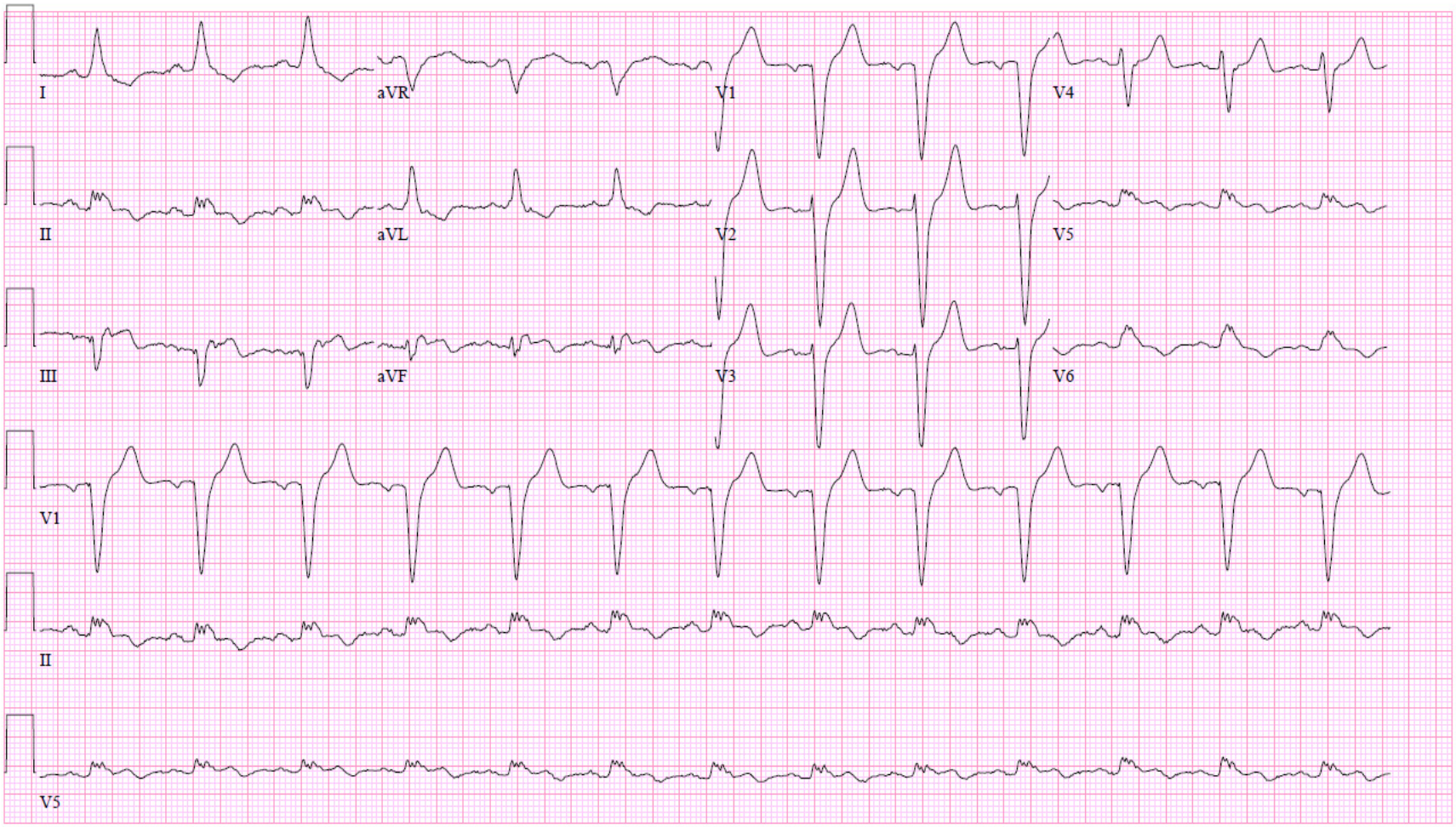
Vent. rate	79	BPM
PR interval	174	ms
QRS duration	140	ms
QT/QTc	438/502	ms
P-R-T axes	50 -9	174

21 y.o. White Male Middle Distance Runner

Technician: TN
Test ind:NOBILL

Referred by:

Confirmed By:

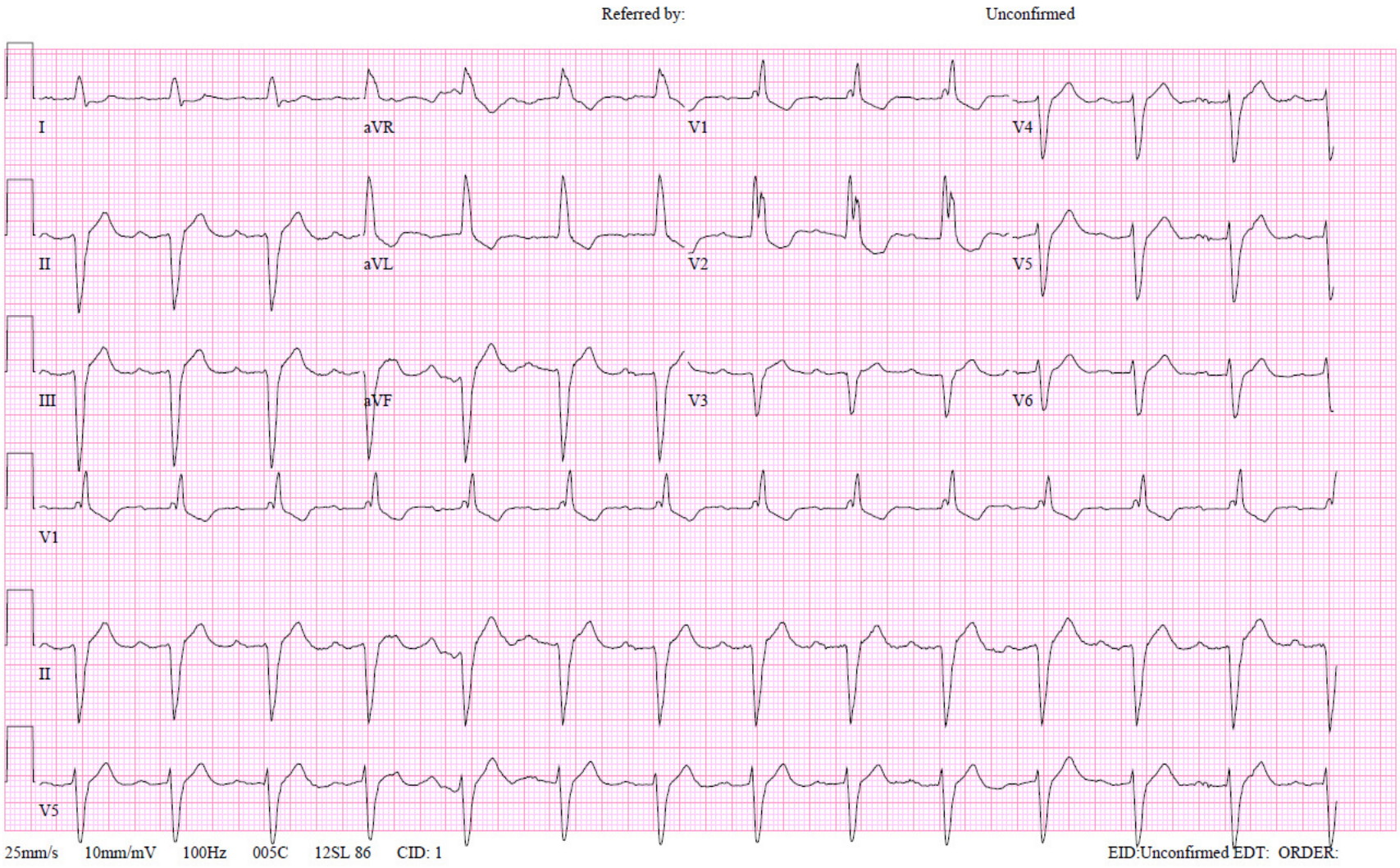


25mm/s 10mm/mV 40Hz 005C 12SL 233 CID: 1

EID:202 EDT: 10:45 11-JUN-2004 ORDER:

ECG#17

30 y.o. White Male Power Lifter

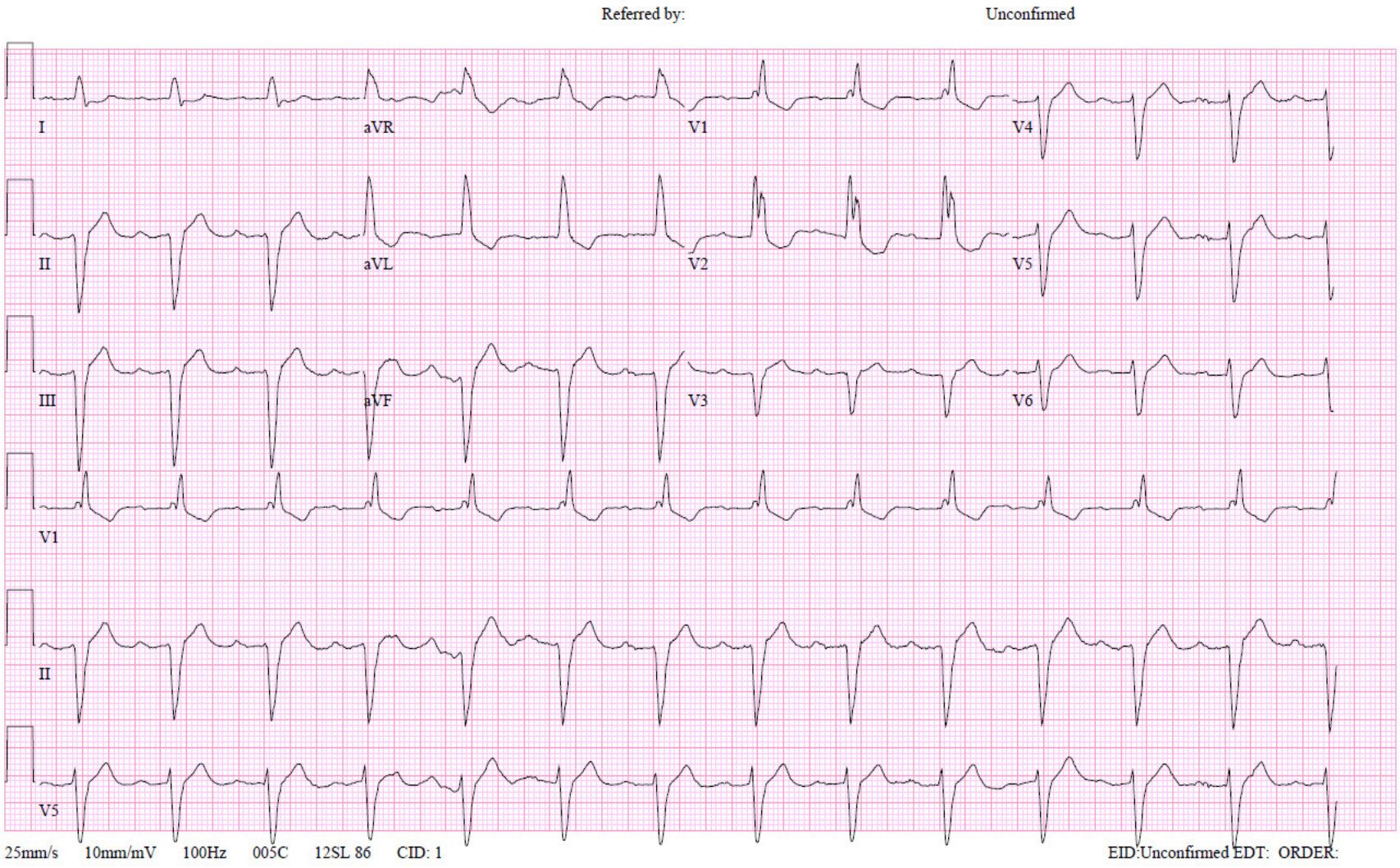


ARS ECG #17:

Audience Response

ECG#17

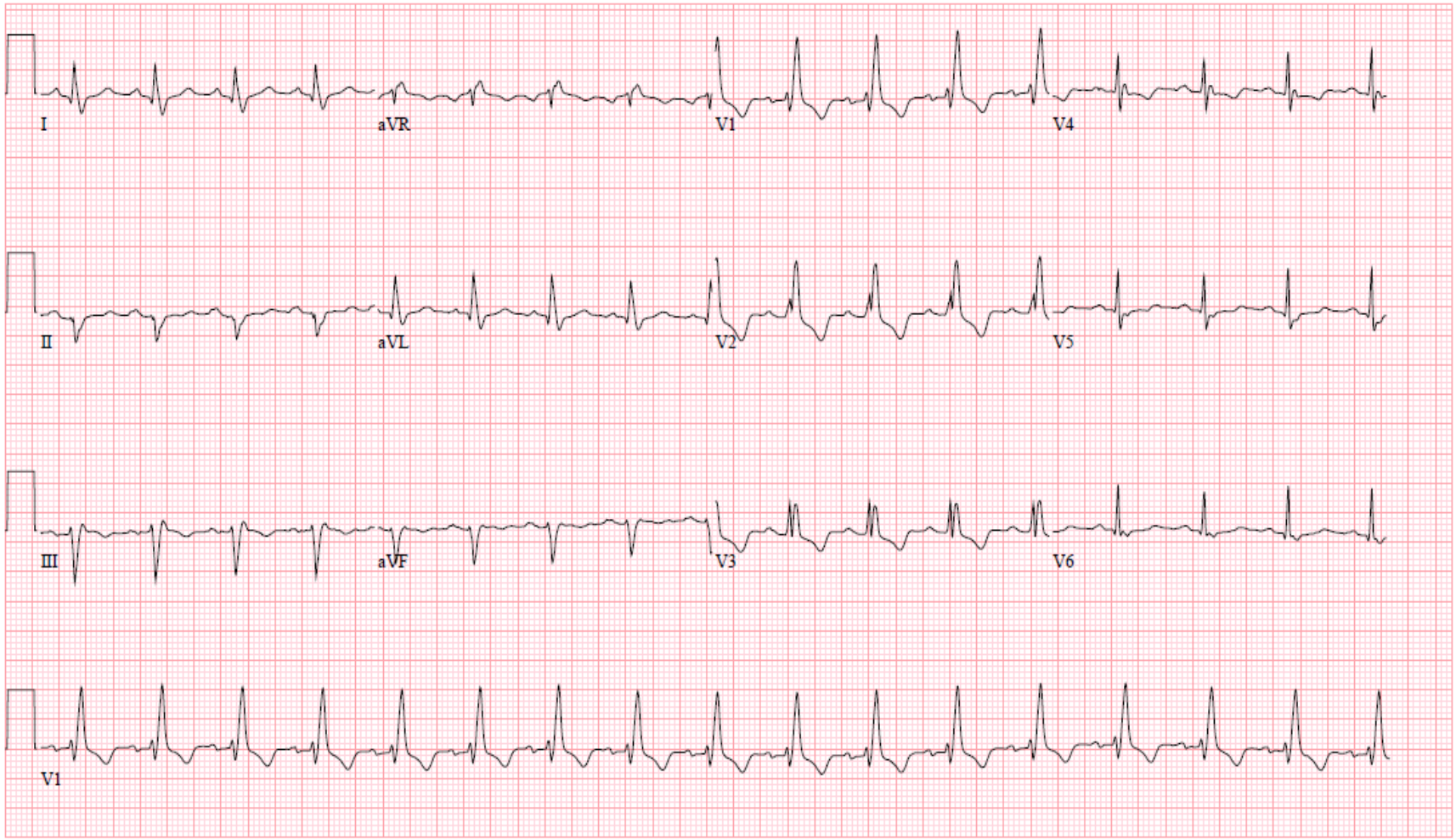
30 y.o. White Male Power Lifter



ECG#18

Vent. rate	100	BPM
PR interval	154	ms
QRS duration	134	ms
QT/QTc	374/482	ms
P-R-T axes	44 -66	16

21 y.o. White Male Rower



25mm/s 10mm/mV 40Hz 8.0 SP2 12SL 241 CID: 0

EID:202 EDT: 09:32 21-MAY-2013 ORDER:

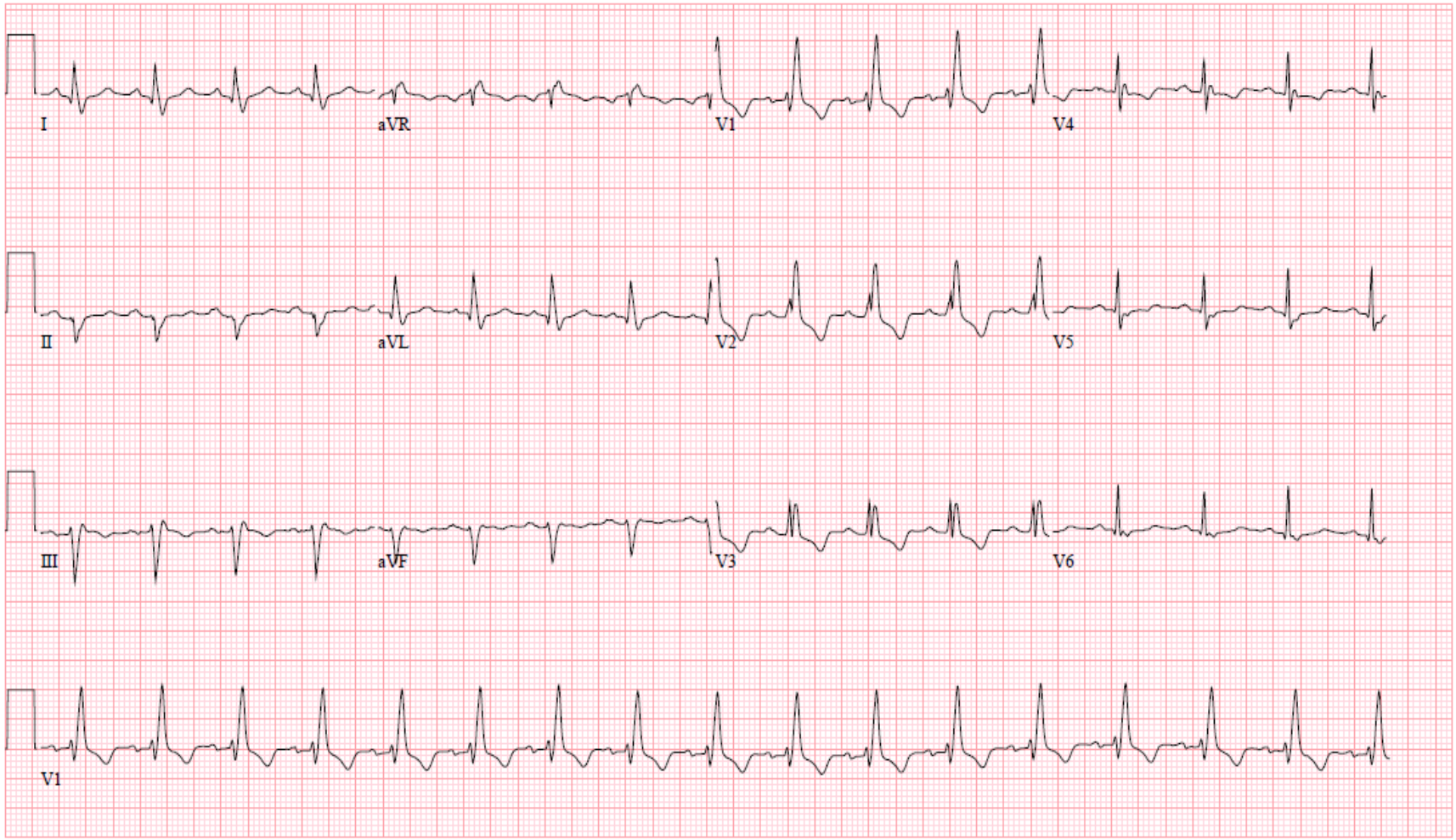
ARS ECG #18:

Audience Response

ECG#18

Vent. rate	100	BPM
PR interval	154	ms
QRS duration	134	ms
QT/QTc	374/482	ms
P-R-T axes	44 -66	16

21 y.o. White Male Rower



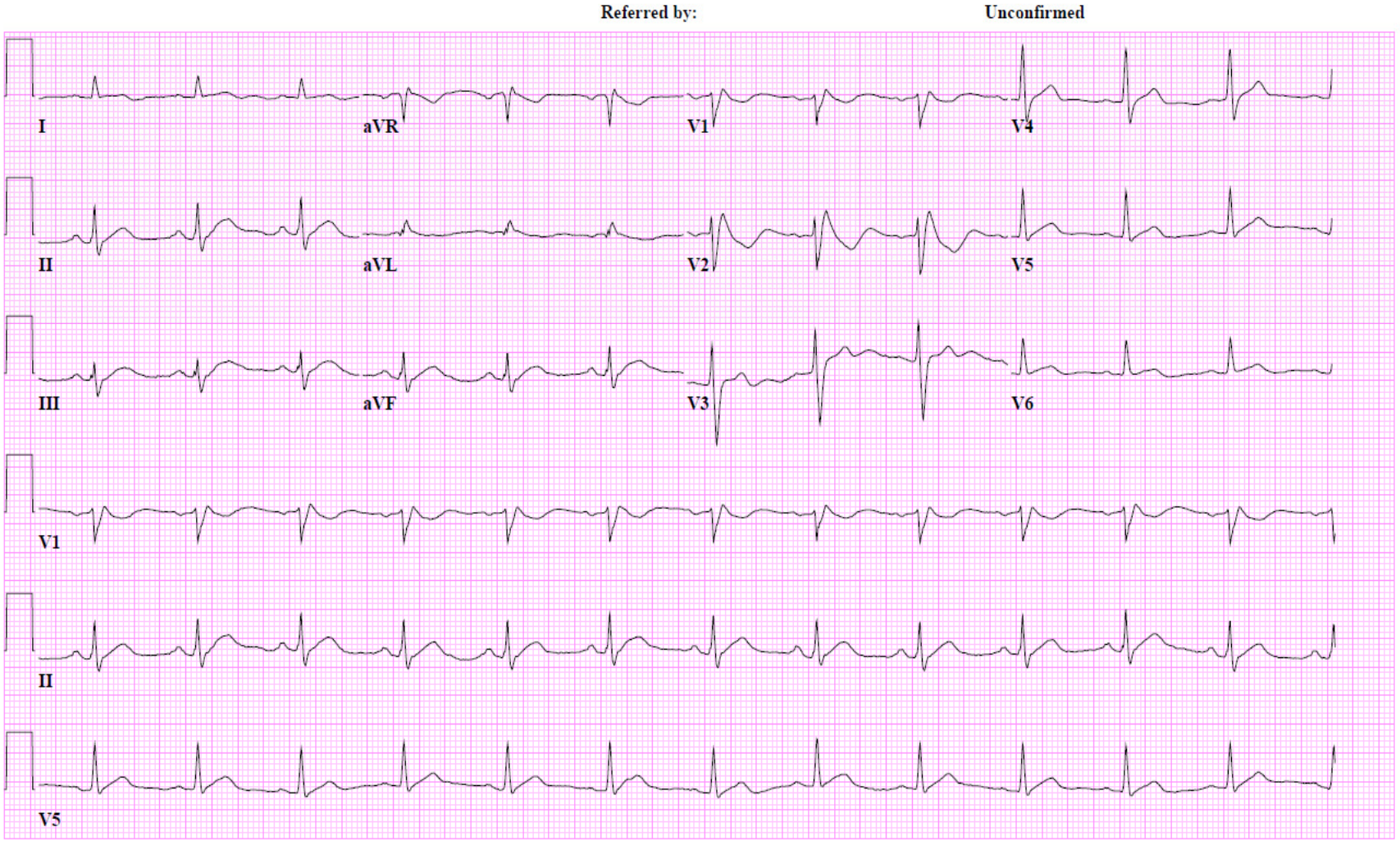
25mm/s 10mm/mV 40Hz 8.0 SP2 12SL 241 CID: 0

EID:202 EDT: 09:32 21-MAY-2013 ORDER:

ECG#19

Vent. rate	75	BPM
PR interval	175	ms
QRS duration	117	ms
QT/QTc	363/405	ms
P-R-T axes	78 36	85

24 y.o. Asian Male Golfer



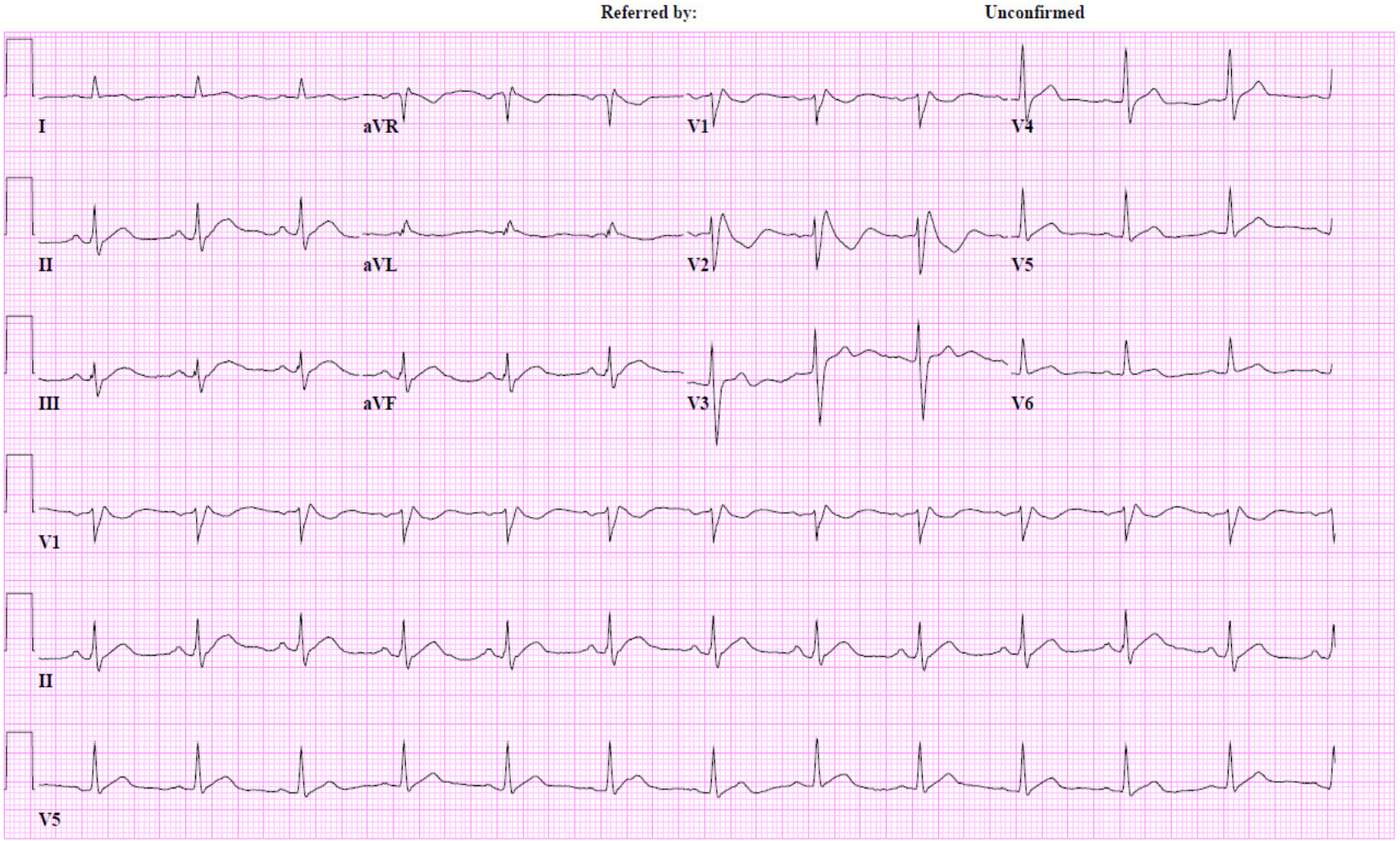
ARS ECG #19:

Audience Response

ECG#19

Vent. rate	75	BPM
PR interval	175	ms
QRS duration	117	ms
QT/QTc	363/405	ms
P-R-T axes	78 36	85

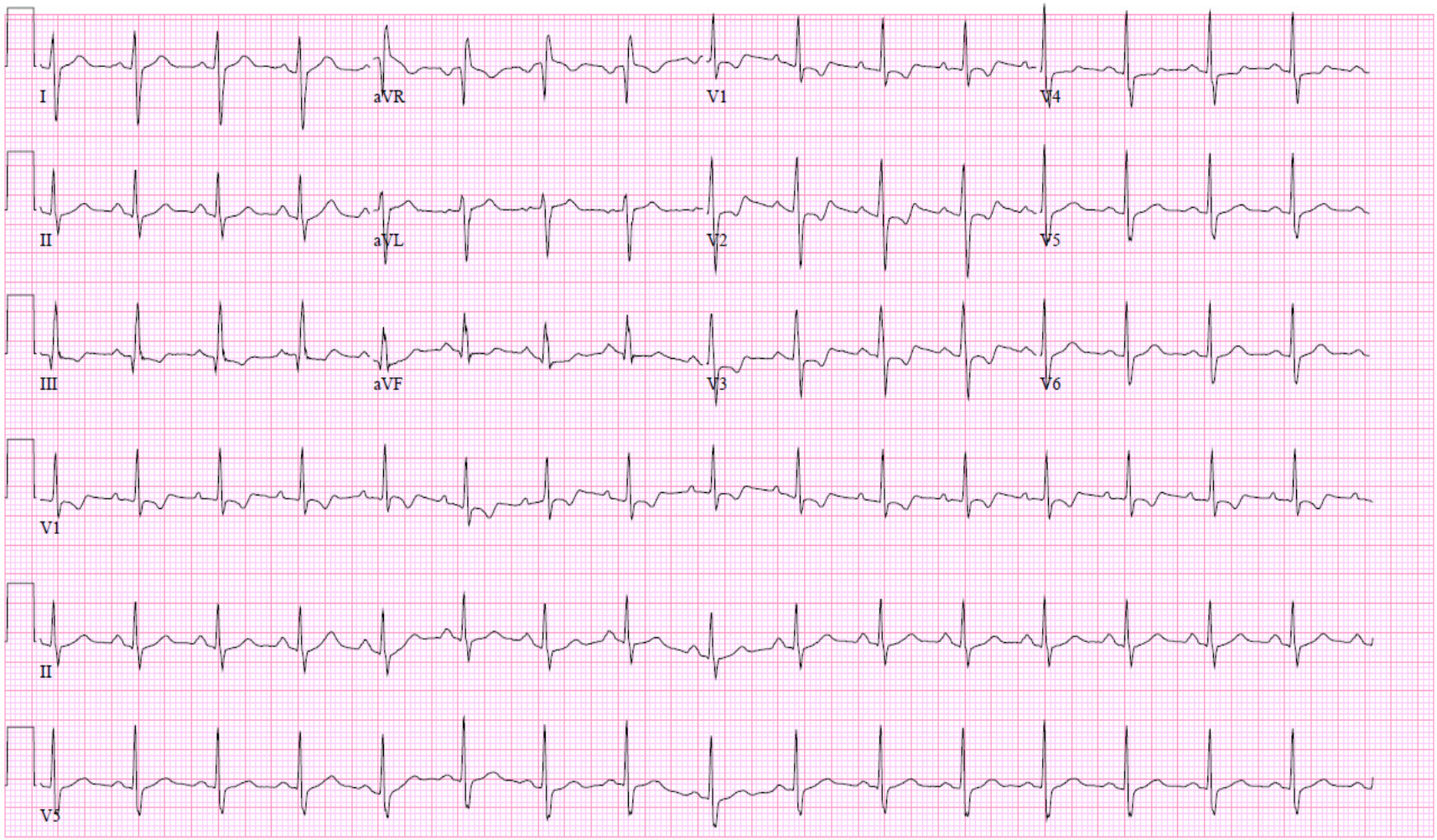
24 y.o. Asian Male Golfer



ECG#20

Vent. rate	96	BPM
PR interval	146	ms
QRS duration	100	ms
QT/QTc	333/421	ms
P-R-T axes	60 117 27	

18 y.o. White Female Cheerleader



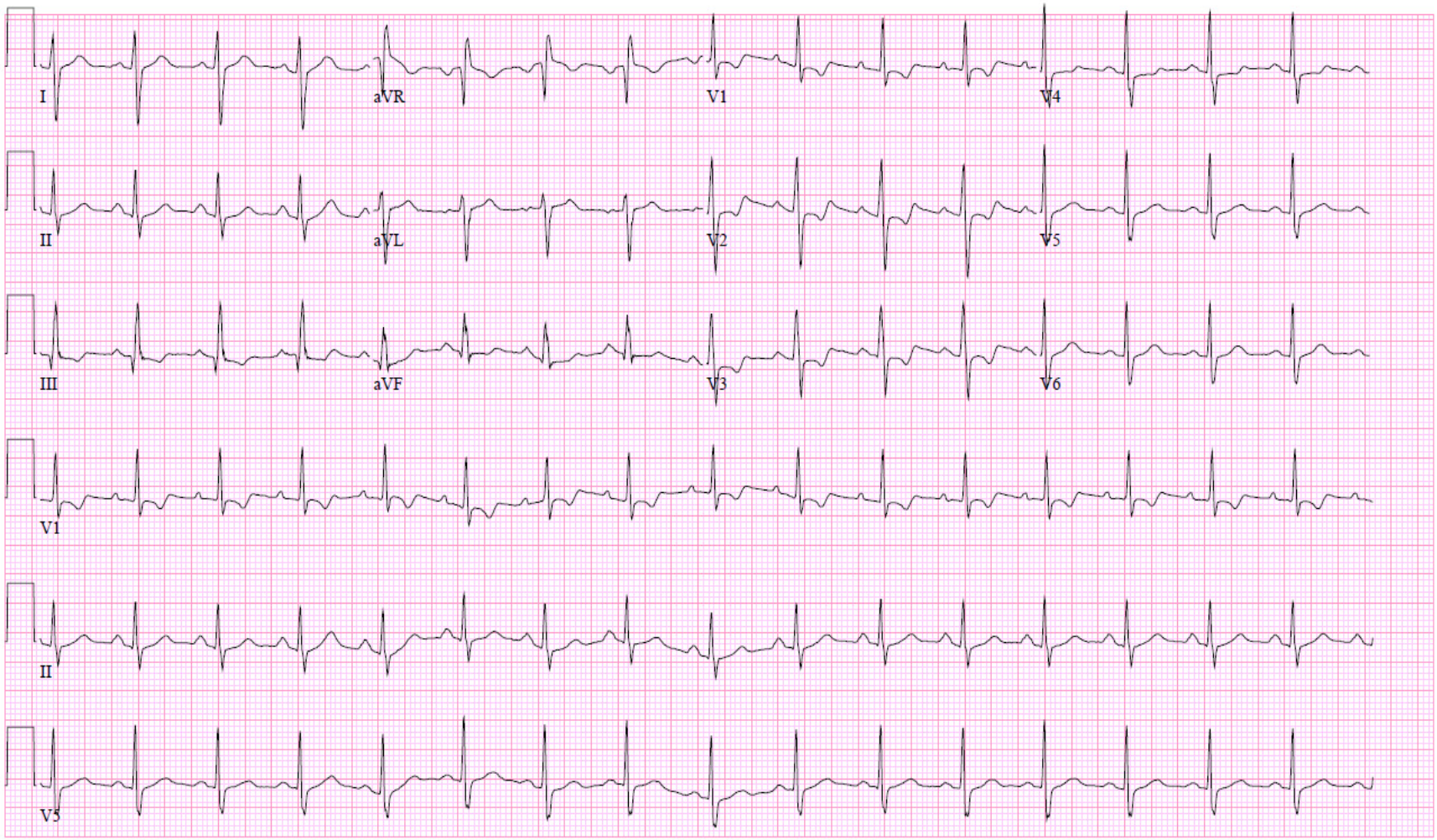
ARS ECG #20:

Audience Response

ECG#20

Vent. rate	96	BPM
PR interval	146	ms
QRS duration	100	ms
QT/QTc	333/421	ms
P-R-T axes	60 117 27	

18 y.o. White Female Cheerleader



Thank You !

MGH 1811 Cardiovascular Performance Program