Association between electrocardiographic and echocardiographic right ventricular hypertrophy in a military cohort in Taiwan: The CHIEF study

ECG criteria for RVH

Fan-Chun Meng, Yen-Po Lin, Fang-Ying Su, Yun-Shun Yu, Gen-Min Lin

Departments of Medicine, Hualien-Armed Forces General Hospital, Hualien, Taiwan
Department of Emergency Medicine, Tzu-Chi General Hospital, Taipei Branch, New Taipei City, Taiwan
Department of Public Health, Tzu-Chi University, Hualien, Taiwan
Department of Electric Engineering, National Dong-Hwa University, Hualien, Taiwan

Abstract

We compared electrocardiographic and echocardiographic right ventricular hypertrophy (RVH) in 264 military members in Taiwan. The correlations of the Myers et al. and Sokolow-Lyon criteria with RV wall thickness were low ($r < 0.1$). Our data supported the American guidance that RVH voltage criteria violations should not receive further echocardiographic investigation.

1. Introduction

The European Society of Cardiology (ESC) in 2010 recommended that athletes with electrocardiographic (ECG) right ventricular hypertrophy (RVH) should receive further investigation to exclude pathologic right ventricular dilatation or hypertrophy. However, the American Heart Association (AHA) guideline in 2014 did not support the ESC suggestion to use routine ECG screening for athletes since there were high false positive rates as comparing ECG-RVH with cardiac imaging findings. Most of the ECG studies were examined for the White athletes and some for the Black athletes, but there were very few ECG studies regarding the Asian athlete populations. Therefore we aimed to investigate the association between ECG-RVH and echocardiographic RVH in a military cohort with regularly rigorous exercise training in Taiwan.

2. Methods

In the cardiorespiratory fitness and hospitalization events in armed forces (CHIEF) study, we included 264 subjects undergoing both an ECG and an echocardiography at a hospital-affiliated medical clinic. The Sokolow-Lyon criterion-based RVH was defined as a composite of amplitudes (R voltage of V1 + S voltage of V5 or V6) >10.5 mm, and the Myers et al. criterion-based RVH was defined as (1) R/S ratio of V1 >1 or (2) R/S ratio of V5 or V6 <1 or (3) R voltage of V1 >6 mm. Two-dimensional echocardiographic anterior right ventricular wall thickness (RVWT) was measured by the leading edge-to- leading-edge method at the onset of the QRS complex of end diastole from the parasternal long-axis window. Echocardiographic RVH was defined as anterior RVWT >5.5 mm, the 95th percentile in our cohort.

Pearson’s correlation coefficient ($r$) was used to determine the degree of correlation between each ECG criterion and RVWT, and compared by the Fisher’s z test. The sensitivity and specificity of each ECG criterion for echocardiographic RVH were compared. A two-tailed value of $p < 0.05$ was considered significant. All analyses were performed using SAS version 9.1 (SAS Institute, Cary, NC).
RVWT, right ventricular wall thickness.

Abbreviations

Right Ventricular Wall Thickness in the Military Population.

332

prevalence of ECG-RVH was generally low (0–33.3).

The Prevalence, Sensitivity, Specificity, and Predictive Values of Each Electrocardiographic Criterion for Echocardiographic Right Ventricular Hypertrophy.

Table 1
Baseline Characteristics of Electrocardiographic Measurements and Echocardiographic Parameters in the Military Population.

| Variables                          | Military Participants (n = 264) |
|-----------------------------------|---------------------------------|
| Age (years)                       | 27.3 ± 6.5                      |
| Sex, male (%)                     | 242 (91.7)                      |
| Height (cm)                       | 171.1 ± 6.0                     |
| Weight (kg)                       | 73.6 ± 12.4                     |
| Waist circumference(cm)           | 84.2 ± 10.0                     |
| Current smoker, n (%)             | 105 (39.8)                      |
| Body mass index (kg/m²)           | 25.1 ± 3.9                      |
| Underweight (-< 18.5) (%)         | 8 (3.0)                         |
| Normal (18.5–24.9) (%)            | 139 (52.7)                      |
| Overweight (25–29.9) (%)          | 93 (35.2)                       |
| Obesity (>30) (%)                 | 24 (9.1)                        |
| Body surface area (m²)            | 1.8 ± 0.38                      |
| Systolic blood pressure (mm Hg)   | 122.2 ± 16.3                    |
| Diastolic blood pressure (mm Hg)  | 73.8 ± 12.1                     |
| Heart rate (beats/min)            | 65.7 ± 11.5                     |
| R/S (V1)                          | 0.48 ± 0.52                     |
| R/S (V5 or 6) minimum             | 8.9 ± 8.6                       |
| R (V1) (mm)                       | 3.0 ± 1.9                       |
| Sokolow-Lyon RVH (mm)             | 5.4 ± 3.1                       |
| R(V1) + S(V5 or 6) maximum        | 4.30 ± 0.74                     |
| Prevalence of RVH                 |                                 |
| RVWT >5.5 mm, n (%)               | 12 (4.5%)                       |

Abbreviations: RVH, right ventricular hypertrophy; RVWT, right ventricular wall thickness.

Table 2
Pearson Correlation Coefficient (R) of Electrocardiographic Criteria With Anterior Right Ventricular Wall Thickness in the Military Population.

| ECG criteria                          | RVWT   | R     | p-value |
|---------------------------------------|--------|-------|---------|
| R/S (V1)                              | 0.079  | 0.21  |         |
| R/S (V5 or 6) minimum                 | 0.020  | 0.78  |         |
| R (V1) (mm)                           | 0.0053 | 0.93  |         |
| Sokolow-Lyon RVH (mm)                 | 0.090  | 0.15  |         |
| R(V1) + S(V5 or 6) maximum            |        |       |         |

Abbreviations: ECG, electrocardiography; RVH, right ventricular hypertrophy; RVWT, right ventricular wall thickness.

3. Results

Table 1 shows the baseline characteristics of the military cohort. Table 2 shows that both the Myers et al. and Sokolow-Lyon ECG voltage criteria were not correlated with echocardiographic anterior RVWT (r = 0.0053–0.090). Table 3 reveals that the prevalence of ECG-RVH was generally low (0–0.76%) and so was the sensitivity of each ECG criterion for RVH (0–16.7%). In contrast, most of the specificities were greater than 90%. The positive predictive value was estimated from 0 to 7.7%. However, the negative predictive values were all greater than 94%.

4. Discussion

The ECG criteria were not sensitive to identify echocardiographic RVH and the positive predictive values were low. In contrast, both the specificity and negative predictive values of each ECG criterion for echocardiographic RVH were high in our military cohort. To our best knowledge, high specificity/negative predictive values and low sensitivity/positive predictive values are common features for non-gold standard diagnostic tests utilized in a cohort of low pre-test probability of disease.

We acknowledged that the low prevalence of ECG-based RVH is not only present in our overall 4,080 military participants in Taiwan but also in a large sample of 2,533 Caucasian athletes (0.9% and 2.0% respectively). Similarly, ECG-based RVH may not be commonly coexisted with other right ventricular pathologies. Zaidi et al. revealed that the prevalence of the Sokolow-Lyon ECG-RVH in patients with arrhythmogenic right ventricular cardiomyopathy (ARVD) was only 1.5%. Accordingly, the sensitivity and positive predictive value of the ECG based-RVH for ARVD was also estimated less than 1.5%.

Although it is a simple estimate of RVH by using RVWT >5.5 mm in young- to-middle aged adults, the echocardiographic quantitative assessment of RV mass has been difficult due to the complex RV anatomy. In the Multi-Ethnic Study of Atherosclerosis (MESA), RV mass was precisely measured by cardiac magnetic resonance (CMR) imaging and the results were in line with the findings in several echocardiographic studies that low sensitivity/positive predictive values and high specificity/negative predictive values of the Myers et al. and Sokolow-Lyon ECG criteria for the CMR defined RVH in a middle- to-old aged multi-ethnic population free of clinical cardiovascular disease.

In conclusion, our data supported the American guidance that RVH voltage criteria violations should not prompt further echocardiographic investigation among military members in Taiwan.

References

1. Corrado D, Pelliccia A, Heidbuchel H, et al. Section of Sports Cardiology, European Association of Cardiovascular Prevention and Rehabilitation. Recommendations for interpretation of 12-lead electrocardiogram in the athlete. Eur Heart J. 2010;31:243–259.

2. Maron BJ, Friedman RA, Klugfeldt P, et al. American Heart Association Council on Clinical Cardiology, Advocacy Coordinating Committee, Council on Cardiovascular Disease in the Young, Council on Cardiovascular Surgery and Anesthesia, Council on Epidemiology and Prevention, Council on Functional Genomics and Translational Biology, Council on Quality of Care and Outcomes Research, and American College of Cardiology. Assessment of the 12-Lead ECG as a screening test for detection of cardiovascular disease in healthy general populations of young people (12–25 Years of Age): a scientific statement from the American Heart Association and the American College of Cardiology. Circulation. 2014;130:1303–1334.

3. Lin GM, Li YH, Lee CJ, et al. Rationale and design of the cardiopulmonary fitness and hospitalization events in armed forces study in Eastern Taiwan. World J Cardiol. 2016;8:464–471.

4. Sokolow M, Lyon TP. The ventricular complex in left ventricular hypertrophy as obtained by unipolar precordial and limb leads. Am Heart J. 1949;37:161–186.

5. Myers GB, Klein HA, Stofer BE. Electrocardiographic diagnosis of right ventricular hypertrophy. Am Heart J. 1948;35:1–40.

Table 3
The Prevalence, Sensitivity, Specificity, and Predictive Values of Each Electrocardiographic Criterion for Echocardiographic Right Ventricular Hypertrophy.

| ECG Criteria                          | Prevalence(%) | Sensitivity(%) | Specificity(%) | PPV(%) | NPV(%) |
|---------------------------------------|---------------|----------------|----------------|--------|--------|
| RVWT >5.5 mm                          | 4.55          | 8.3            | 93.7           | 5.9    | 95.6   |
| R/S (V1) >1                           | 0.38          | 8.3            | 93.7           | 5.9    | 95.6   |
| R/S (V5 or 6) minimum <1              | 0.76          | 16.7           | 71.0           | 2.7    | 94.7   |
| R (V1) >6 mm                          | 0             | 0              | 95.6           | 0      | 95.3   |
| Sokolow-Lyon RVH >10.5 mm             | 0.38          | 7.1            | 94.8           | 7.7    | 95.6   |

Abbreviations: ECG, electrocardiography; NPV, negative predictive value; PPV, positive predictive value; RVH, right ventricular hypertrophy; RVWT, right ventricular wall thickness.
6. Rudski LG, Lai WW, Afilalo J, et al. Guidelines for the echocardiographic assessment of the right heart in adults: a report from the American Society of Echocardiography endorsed by the European Association of Echocardiography, a registered branch of the European Society of Cardiology, and the Canadian Society of Echocardiography. J Am Soc Echocardiogr. 2010;23:685–713.

7. Gati S, Sheikh N, Ghani S, et al. Should axis deviation or atrial enlargement be categorised as abnormal in young athletes? The athlete's electrocardiogram: time for re-appraisal of markers of pathology. Eur Heart J. 2013;34:3641–3648.

8. Zaidi A, Ghani S, Sheikh N, et al. Clinical significance of electrocardiographic right ventricular hypertrophy in athletes: comparison with arrhythmogenic right ventricular cardiomyopathy and pulmonary hypertension. Eur Heart J. 2013;34:3649–3656.

9. Jurcut R, Giusca S, La Gerche A, et al. The echocardiographic assessment of the right ventricle: what to do in 2010. Eur J Echocardiogr. 2010;11:81–96.

10. Whitman IR, Patel VV, Soliman EZ, et al. Validity of the surface electrocardiogram criteria for right ventricular hypertrophy: the MESA-RV Study (Multi-Ethnic Study of Atherosclerosis-Right Ventricle). J Am Coll Cardiol. 2014;63:672–681.