Cardiovascular Screening in the U.S. Military: Time to Reconsider the Electrocardiogram

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ABSTRACT

Introduction

The US Department of Defense (DoD) has adopted a model concept of the warrior athlete. Identifying latent disease that could compromise the military operator is critical to the warrior athlete concept. Cardiovascular complaints are the important problem recognized in service members evacuated from combat zones, and the incidence of sudden cardiac death in U.S. military recruits is comparable to or greater than that among National Collegiate Athletic Association Athletes. Nevertheless, the mandatory electrocardiogram (ECG) was removed from official U.S. military accession screening policy in 2002. Inclusion of ECG screening in high risk athletics is increasingly recognized as appropriate by professional organizations such as the American Heart Association and American Medical Society for Sports Medicine, though neither recommends ECG for generalized screening in large, low-risk populations.

Materials and Methods

The appropriate DoD instructions were reviewed in the context of recent literature regarding the sensitivity and specificity of ECG screening for prevention of sudden cardiac arrest or debilitating arrhythmias.

Results

Challenges to implementation of ECG as a screening modality in U.S. military accessions include clinician interpretation validity and reliability. Modern interpretation criteria and new interpretation technology each serve to mitigate these recognized limitations. Outside experience with implementation of modern ECG suggest potential benefits are significant in the highest risk military groups.

Conclusion

Prospective study of ECG screening is needed to determine the impact on cardiovascular outcomes in U.S. military populations.

INTRODUCTION

The Warrior Athlete

The US Department of Defense (DoD) model of warrior fitness and care has evolved over the last decade into the concept of the warrior athlete. In 2009, Special Operations Command introduced a novel approach to warrior care by establishing the Tactical Human Optimization, Rapid Rehabilitation and Reconditioning (THOR3) program. This program reflects an investment in "Truth Number 1" of special operations forces: "Humans are more important than hardware." Identifying latent disease that will compromise the military operator is critical to the warrior athlete concept.

US military accession medical standards were first developed in 1917 during World War I to address prevalent diseases with important morbidity and mortality such as tuberculosis. The institution of compulsory chest X-ray was largely responsible for the >10-fold reduction in military tuberculosis hospital admission rates from 11.8 per 1,000 during World War I to <1 per 1,000 in World War II.[1]

The first unified DoD medical standard was released in 1986 as Department of Defense Instruction (DoDI) 6130.4,[2] providing an organ systems-based register of disqualifying medical conditions. Revised in 1994, 2000, 2004, replaced in 2010 by DoDI 6130.03 "Medical Standards for Appointment, Enlistment, or Induction into the Military Services" and updated in 2018, the instruction establishes medical standards across the DoD for appointment, enlistment, or induction into military service. These standards apply to officer candidates and enlisted recruits alike. The US Military Entrance Processing Command (MEPCOM) processes all recruits for enlisted service. The Department of Defense Medical Evaluation Review Board (DODMERB) evaluates all officer candidates for medical qualification before commissioning. Both DODMERB and MEPCOM adhere to DoDI 6130.03.

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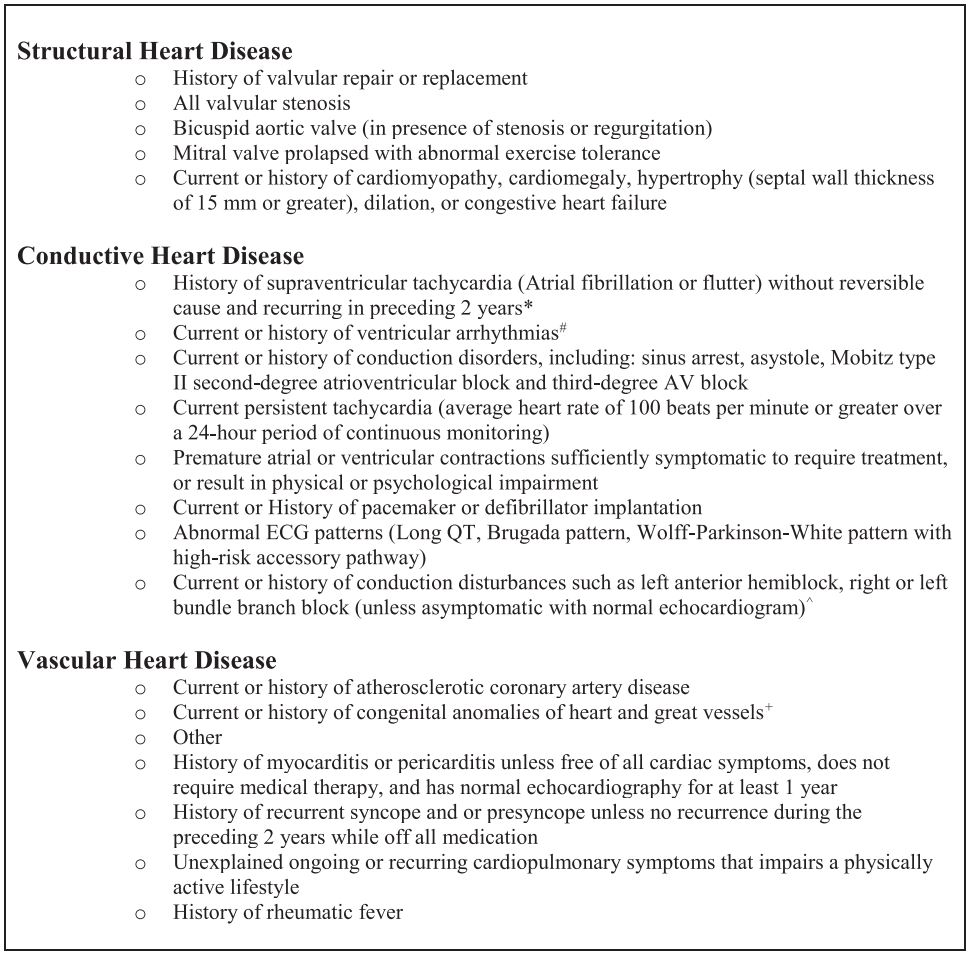

FIGURE 1. List of heart conditions that do not meet the standard for appointment, enlistment, or induction for service in U.S. military according to DoDI 6130.03, April 28, 2010. *An identified atrioventricular nodal reentrant tachycardia or atrioventricular reentrant tachycardia (such as Wolff Parkinson White syndrome) having completed successful ablative therapy without recurrence of symptoms after 3 months and normal electrocardiogram meets the standard. #Occasional asymptomatic unifocal premature ventricular contractions meet the standard. ^If asymptomatic with a normal echocardiogram meets the standard. +Dextrocardia with situs inversus without other anomalies, ligated or occluded patent ductus arteriosus, corrected atrial septal defect or patent foramen ovale without residua, and corrected ventricular septal defect without residua with an otherwise normal echocardiogram within 6 months meet the standard.

Why Screen Military Applicants for Cardiovascular Disease?

The importance of accurately identifying military applicants (officer and enlisted) with cardiovascular disease is difficult to exaggerate. In 2007, more than half of those medically evacuated from Iraq and Afghanistan to Landstuhl had cardiovascular chief complaints, versus only 20% for combat wounds.[3] Sudden death is catastrophic for the individual, but incapacitation because of a nonfatal illness (such as supraventricular tachycardia) can compromise a critical mission and jeopardize many more lives. The current DoDI 6130.03 classifies disqualifying heart conditions into 19 categories covering structural, electrical, and vascular heart conditions that may directly interfere with expected performance within military service. It is worth noting that many asymptomatic but disqualifying heart disease conditions (such as latent hypertrophic cardiomyopathy or Wolff Parkinson White, see Fig. 1) may be detectable only on a screening ECG (Table I). Many of the conditions likely to be detectable on screening ECG are known causes of SCD in active duty military populations.[4,5] In the context of SCD epidemiology in the military, ECG may detect pathology in over 75% of the known causes of sudden cardiac death (SCD), and potentially over 90% if postmortem idiopathic causes are related to arrhythmic etiology. Yet, there are several important conditions, such as anomalous coronary arteries, which would not be detectable with ECG. Nonetheless, universal ECG screening is not a component of current medical evaluation of military applicants.

SCD in U.S. Military Recruits

Basic training in the U.S. military combines significant physical and mental challenges that are analogous to intensive sport activities. Sudden unexplained death is the leading cause of nontraumatic sudden death in U.S. military populations.[5,6] Of the known causes of nontraumatic sudden death, SCD remains

TABLE I. Disqualifying Cardiac Disease Potentially Identified by ECG Screening

ECG **Likely** to Identify	ECG **Not Likely** to Identify
Atherosclerotic coronary artery disease	
Hypertrophic cardiomyopathy (HCM)	Coronary anomalies
Arrythmogenic right ventricular cardiomyopathy (ARVC)	Catecholaminergic polymorphic ventricular tachycardia (CPVT) syndrome
Long/short QT syndromes	Idiopathic ventricular fibrillation
Brugada syndrome	Commotio cordis
Congenital AS	
Myocarditis (if concomitant myopericarditis)	

the leading cause in U.S. military populations and specifically, enlisted recruits in training. Autopsy data from the DoD Recruit Mortality Registry (DoD-RMR) for military recruit populations undergoing basic military training in the years from 1977 to 2001 demonstrates SCD accounts for over half of the estimated 13.0 nontraumatic sudden deaths per 100,000 recruit-years across all military services.[5] Importantly, 108 of the 126 nontraumatic sudden deaths were related to exercise and over half of cases demonstrated a clearly identifiable cardiac abnormality at autopsy. It is worth noting that a substantial number—4.5 deaths per 100,000 recruit-years—were categorized as "idiopathic," because no abnormality was detected at autopsy. Twelve idiopathic deaths were associated with sickle-cell trait, accounting for 31% of the exercise-associated idiopathic sudden deaths which was consistent with previous report.[6] It is reasonable to conjecture that many of the remaining idiopathic deaths may have had arrhythmic syndromes that are not associated with structural abnormalities. Age, gender, and ethnicity were identified as important risk factors. In recruits $\leq$ 19 years of age, SCD mortality was $\sim$6.6 per 100,000 recruit-years (Table II). This figure increases to 14.4 per 100,000 recruit-years in the 25 and older population. Male enlisted recruits were more likely to experience sudden death than females; there were 7.1 and 3.8 cardiac deaths per 100,000 recruit-years, respectively. Analysis by ethnicity found African American cardiac death rates to be 12.0 per 100,000 recruit-years, over twice as common as the non-African American cardiac death rate of 5.3/100,000 recruit-years.[4,5]

SCD in Active Component of U.S. Military Services

Beyond risk of SCD in basic training environments, Smallman et al. analyzed data from the Defense Medical Epidemiology Database (DMED) for SCD associated with exertion in active duty (full-time) U.S. military service members from 2005 to 2010.[4] The retrospective database study suggests the incidence of SCD to be at least 1.63 per 100,000 person-years overall, rising to at least 3.84 per 100,000 person-years for age 35 and older, with 78% of these attributable to atherosclerotic disease. This study highlights risk factors in the active duty military population including: black race, male gender, sickle cell trait, army service, and report of chest pain within 6 months of SCD. Specifically, this study confirms the association with sickle cell trait reported previously by Kark et al.[7] and others.[8–10]

Comparison to NCAA Athletes

A recent review concluded the incidence of SCD in athletes to be 2 in 100,000 college athletes and 1.3 in 100,000 high school athletes.[11] SCD rates appear to be tied to the intensity of exercise. NCAA Division 1 basketball players are at substantially higher risk of exertional sudden death (19.2/100,000 athlete-years), compared with all other NCAA athletes (1.86/100,000 athlete-years).[12] These numbers have also been reported per 100,000 person-years and vary from 0.5 to 2.3 per 100,000 person-years.[13] As previously pointed out, the incidence of SCD in military recruits in recruits age 19 and younger is $\sim$6.6/100,000 recruit-years, but increases by over 2-fold to 14.4/100,000 recruit-years in the 25 and older population. As one can see, military recruit death rates appear higher than the collegiate cohort, but less than that reported in collegiate basketball players.

Cardiovascular Screening Strategy

Current cardiovascular screening of military applicants includes a DoD-specific history and physical examination to screen for cardiovascular disease. In 2002, support for obtaining a compulsory resting 12-lead ECG was withdrawn by then Assistant Secretary of Defense for Health Affairs, Dr. William Winkenwerder.

After 2002, the ECG became an optional modality available Military Entrance Process Station (MEPS) physician with clinical concern for underling cardiovascular disease[14] in enlisted recruits and similarly for officer candidates obtaining medical evaluations for the DODMERB. Nevertheless, a preparticipation resting 12-lead ECG remains a requirement for all applicants before enrollment in high-intensity military training programs such as the survival, evasion, resistance, and escape course[15]; and entrance into elite military units such as the US Army Rangers or US Navy Seals. The authors have identified no published or unpublished study of the performance of ECG as a screening tool in these select populations. Additionally, all new applicants applying at age 40 and older are required to have a resting 12-lead ECG as well.[16]

Special forces aside, the current DoD screening strategy employs a mandatory history[17] and physical examination[18] to assess cardiovascular risk in eligible enlisted recruits at a MEPS site.[19–21] An initial prescreen questionnaire[22] contains self-reported data elements and requires explanations for positive answers. The military prescreen queries for "periods of

TABLE II. Reported Incidences of SCD Across Relevant Clinical Populations (per 100,000 Person Years)[4,5,28]

Reported Incidences of SCD Across Relevant Clinical Populations (Expressed per 100,000 Person-Years)	Overall	Male	Female	AA	Non-AA
Military recruits (DoD-RMR[4])	6.6*	7.1*	3.8*	12.0*	5.3*
Active duty military (DoD-CDR[5])	n/a	6.7	1.4	n/a	n/a
NCAA athletes [28]	2.3	3.0	1.3	5.7	1.7

Note: DoD-RMR, Department of Defense Recruit Mortality Registry; DoD-CDR, Department of Defense Cardiovascular Death Registry; AA, African American; Non-AA, Non-African American.
*Does not include sudden deaths with normal autopsy findings and so may be an underestimate of cardiac deaths.

unconsciousness", "fainting spells or passing out," but does not address the American Heart Association (AHA) elements "exertional chest pain/discomfort" or "excessive exertional and unexplained dyspnea/fatigue, associated with exercise"[19] (Table III). Other differences include questions regarding a personal history of screening or restriction from sport, family history, and exam findings; MEPS providers are free to inquire at their discretion. When clinical concern for underlying cardiac disease arises, the MEPS provider may order an ECG to determine service qualification.

As of October 1, 2019, a contract awarded to USMEPCOM to provide ECG interpretation in <24 hours has identified the process cost per ECG at <$30 per ECG interpreted.[23] Previous analysis and cost estimates for ECG screening programs in NCAA athlete populations suggests a cost-effectiveness ratio of $42,900 per life-year saved when compared with history and physical examination alone.[24] This estimate uses a per-athlete incremental cost of $89, suggesting the current MEPS process cost of $30 per ECG may prove even more cost-effective; however, a direct analysis has not been published for this population at risk. However, if the mandatory military screening does not identify abnormalities concerning for cardiac condition, no further cardiac risk assessment is necessarily required.

Why Not Include the ECG in Military Recruit Screening?

Given the relatively high rate of sudden death among recruits, the military would seem to be an appropriate context to reintroduce ECG screening. The rationale for eliminating universal screening was not given in the 2002 memorandum, but may represent a perception that the ECG was too expensive or insufficiently specific.

Available cost estimates are difficult to compare directly. Drehner et al. analyzed data from air force recruit deaths from 1956 to 1996 to assess SCD.[25] They determined SCD at 7.1 per 100,000 air force recruit-years. Acknowledging ECG and even echocardiography may reveal important pathologies (such as cardiomyopathy), the authors assessed difficult-to-screen conditions such as anomalous coronary artery would require cardiac catheterization to effectively diagnose. Such broad considerations contributed to the estimate of $4 million by the air force to prevent one cardiac-related death if implementing compulsory ECG screening.[25] This figure assumes ECG false-positive rates before modern interpretation criteria and an expanded aperture of cost. The authors consider cost of cardiac catheterization for diagnosing anomalous coronary artery, a condition unlikely to be discovered using available screening tools.

Other approaches to cost have identified the incremental cost of adding ECG to history and physical examination, similar to that performed in military applicants, as nominal. Analysis of ECG as a component of preparticipation screening in 1,473 NCAA athletes assessed cost between strategies of history and physical examination with ECG and without ECG.[26] In this study, evaluation followed a clear protocol for evaluating every abnormality. Cost was exact and clearly disclosed for each diagnostic test, including echocardiogram, magnetic resonance imaging, Holter monitors, treadmill stress tests, and electrophysiologic studies. In total, the authors identified the net cost of history and physical examination with and without ECG to be $68,893 and $68,745, respectively. Furthermore, adding ECG effectively discovered significant cardiac pathology missed by history and physical examination alone.[26]

False positive rates associated with ECG screening of young, healthy subjects have previously been identified as unacceptably high. A review of 1,099 candidates for military pilot training using traditional criteria found that 44% of subjects had at least one abnormal finding, while only 0.6% had an actual disqualifying condition identified by ECG.[27] On the other hand, 94% of these abnormalities were because of sinus bradycardia, first degree AV block, and other findings consistent with a healthy athletic heart. Modern ECG algorithms intended for use in athletes such as the Seattle Criteria would not interpret these tracings as abnormal.[28] Additionally, concerns have been raised regarding whether primary care physicians can reliably interpret the ECG, even when applying modern criteria. Nonspecialist physicians at an academic military medical center demonstrated limited reliability and accuracy for ECG interpretation according to modern ECG interpretation criteria without statistically significant differences between clinician subgroups.[29]

Alternatively, the physical examination as a means of identifying cardiovascular disease has poor inter-rater reliability, with a kappa of 0.11 between two sports medicine and

TABLE III. Comparison of American Heart Association (AHA) Recommendations for Preparticipation Screening of Competitive Athletes[36] to Military Prescreen and Military Entrance Processing Station (MEPS) [19–21]

Comparison of American Heart Association (AHA) Recommendations for Preparticipation Screening of Competitive Athletes to Military Prescreen and Military Entrance Processing Station (MEPS)		
	AHA 14-element screening recommendations	Military prescreen & MEPS
Personal history	1. Exertional chest pain/discomfort	DD 2807-1 "Have you ever had or do you now have: Pain or pressure in the chest"
	2. Unexplained syncope/near-syncope	DD 2807-2 "Have you ever had or do you now have: periods of unconsciousness; fainting spells or passing out"
		DD 2807-1 "Have you ever had or do you now have: Dizziness or fainting spells; A period of unconsciousness or concussion"
	3. Excessive exertional and unexplained dyspnea/fatigue, associated with exercise	DD 2807-1 "Have you ever had or do you now have: shortness of breath"
	4. Prior recognition of a heart murmur	DD 2807-1 "Have you ever had or do you now have: Heart trouble or murmur"
		DD 2807-2 "Have you ever had or do you now have: heart murmur, valve problem or mitral valve prolapse"
	5. Elevated systemic blood pressure	DD 2807-1 "Have you ever had or do you now have: high or low blood pressure"
		DD 2807-2 "Have you ever had or do you now have: High blood pressure"
	6. Prior restriction from participation in sports	No screening elements
	7. Prior testing for the heart, ordered by a physician	No screening elements
Family history	8. Premature death (sudden and unexpected, or otherwise) before age 50 years because of heart disease, in ≥1 relative	No screening elements
	9. Disability from heart disease in a close relative <50 years of age	No screening elements
	10. Specific knowledge of certain cardiac conditions in family members: hypertrophic or dilated cardiomyopathy, long-QT syndrome or other ion channelopathies, Marfan syndrome, or clinically important arrhythmias	No screening elements
Physical exam	11. Heart murmur	DD 2808 "Clinical evaluation (Check each item in appropriate column): Heart (Thrust, size, rhythm, sounds)
	12. Femoral pulses to exclude aortic coarctation	DD 2808 "Clinical evaluation (Check each item in appropriate column): vascular system
	13. Physical stigmata of Marfan syndrome	DD 2808 "Clinical Evaluation (Check each item in appropriate column): Upper extremities, lower extremities, spine, other musculoskeletal, eyes, heart (Thrust, size, rhythm, sounds)
	14. Brachial artery blood pressure (sitting position)	DD 2808 "Blood pressure"—three readings

one cardiologist screening West Point cadets during athletic preparticipation examination.[30] These studies highlight the limitations of available clinical screening tests to achieve reproducible, valid, and clinically useful results when applied within the military health system.

New technology employing automated ECG algorithms applying modern criteria, for example, the Seattle Criteria, aims to overcome the present limitations of clinician ECG interpretation. These systems attempt to reduce high false positive and false negative rates as well as improve reliability by not reporting findings (ie, sinus bradycardia and first-degree AV block) that are physiologic adaptations in young, healthy athletes as abnormal. Automation further allows identification of ECG patterns indicating underlying pathology while eliminating inter-rater variation across physicians. In theory, this technology applies updatable algorithms in an automated, real-time, point-of-care screening devices, with a single "go" or "no go" readout.[31] Early reports implementing an example of this technology in nearly 2,500 athletes across 14 NCAA division I athletic programs resulted in improved accuracy (validity) and precision (reliability) measures.[32] Data from this ongoing prospective cohort study have demonstrated a robust impact for over 5,258 student-athletes across 17 NCAA programs. Reporting just 11 cases of confirmed disease, the advanced ECG algorithms using a point-of-care device identified 192 positive ECGs, capturing all 13 cases of confirmed disease while demonstrating a low false positive rate of 3.7%. This compares favorably to the false positive rate of 33.3% using history and physical findings. The false-positive rate for history was 33.3%, physical examination 2.0%, and ECG 3.4%. The sensitivity/specificity/positive predictive value for history was 15.4%/66.9%/0.1%, physical examination 7.7%/98.2%/0.9%, compared with ECG, which was 100%/96.6%/6.8%.[34] Although the low prevalence of disease drives the low positive predictive value, it is understood the abnormal ECG is the first step in the evaluation to arrive at specific diagnoses to understand if a disqualifying condition is present. Such follow-on studies may include echocardiography, Holter monitoring, treadmill stress testing, cardiac imaging, or even electrophysiology testing.

Reintroducing screening ECG to the military recruit screening process is not without potential operational challenges. Each MEPS location provides high-volume medical assessment and screening modalities. Adding additional screening testing may cause untenable process limitations. Reassuringly, universal ECG was previously incorporated into the medical screening process at times when recruitment throughput was higher to maintain a larger military, though it remains unclear how reincorporating universal ECG will impact current screening processes. USMEPCOM has already modernized existing processes to include online ECG interpretation with a 24-hour interpretation average (maximum 72-hour) when ECG is deemed necessary.[33] Though maximal throughput while maintaining a 24-hour interpretation window average is not stated (reference news article again). It is expected that further diagnostic evaluation of abnormal ECGs in accordance with USMEPCOM regulation 40-1, with echocardiography for instance, may increase latency for those recruits. It remains encouraging that the performance characteristics of ECG using modern criteria should lead to fewer false positives and generate less latency than previous universal screening. From another perspective, earlier identification of disqualifying conditions optimizes throughput for all remaining applicants. As the DoD does not currently provide treatment for other disqualifying conditions identified on initial or subsequent diagnostic evaluation, it would be unlikely to expect the DoD to accept additional cost of therapeutic procedures to address any identified disqualifying condition.

The ECG alone offers limited diagnostic utility beyond a military screening purpose. Providing applicants echocardiography in accordance with USMEPCOM regulation 40-1 for abnormalities provides an opportunity to address all abnormal findings—false and true positives—and provides the applicant useful medical information with low risk of ending with an undiagnosed electrocardiographic abnormality. Furthermore, prospective assessment for false positives will be possible as all abnormal ECGs will be offered further evaluation. In this regard, criteria can continue to be refined and inform cost and operational processes.

In summary, ECG with modern interpretation criteria represents a potentially cost-effective screening tool to improve identification of disqualifying cardiac conditions and will not require changes to existing waiver processes for disqualifying conditions.

CONCLUSION

Universal ECG screening of athletes appears to lack appeal, given the low prevalence, cost, and risk of untoward effects of misclassification or lifestyle restriction. Yet the value of a resting 12-lead ECG appears to have significantly improved with modern interpretation criteria and appears to represent an important screening tool for rare SCD heart conditions in civilian athlete populations, and for identifying many of the conditions included in DoDI 6130.03. Military service is associated with a higher event rate for cardiovascular disease than most categories of NCAA athletics, and the impact of cardiac events on the military mission can be catastrophic. In this higher risk cohort, the ECG may represent an important safeguard if it can be implemented with acceptable false positive rates and reproducibility.[35] Newer interpretation algorithms, such as the Seattle Criteria,[28] combined with automated technology that reduces interpreter misclassification, represent promising developments. Prospective studies in the U.S. military to assess the impact of ECG screening on cardiovascular endpoints (as well as on military training) are needed.

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