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Review

The impact of novel exercise criteria and indices for the diagnostic and prognostic ability of exercise testing

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ABSTRACT

Exercise testing (ET) stands as one of the most easy, affordable, cost effective, non invasive methods for diagnosing coronary heart disease. Its sensitivity, specificity and prognostic value, especially in the prime era of its implementation in the cardiac diagnostic procedure, is relatively limited. Novel exercise criteria and indices based either on ST segment changes or ST segment independent parameters, such as "Athens QRS score", have greatly improved the diagnostic ability and accuracy of ET. Complex ECG-derived indices linked to ST changes along with the use of right-sided precordial leads have also enhanced the diagnostic accuracy of ET with respect to the extent of ischemic heart disease and the detection of specific culprit vessels. ET contains also a prognostic value, since several ET-derived parameters have been associated with adverse outcome, including ST changes, blood pressure and heart rate response to exercise and duration of exercise.

1. Introduction

Exercise testing (ET) stands as one of the most easy, affordable, cost effective, non invasive methods for diagnosing coronary heart disease (CHD). Even nowadays, it still is a valuable tool in the hands of Cardiologists, mostly as a first-line approach of ischemic heart disease. ET contributes considerably in the detection of undisclosed coronary heart disease, the management of established heart disease, the assessment of the severity of impairment due to ischemia and the evaluation of the effectiveness of therapy.

In spite of the undisputed value of ET in the management of the heart patient, its sensitivity, specificity and prognostic value, especially in the prime era of its implementation in the cardiac diagnostic procedure, is relatively limited. ET interpretation was, and still is, mostly based on ST segment changes during exercise. Diagnostic capability may be improved by heart rate adjustment of the ST depression, QT- and T-wave changes, and ST-recovery loops and hysteresis [1,2].

Since then, there has been a great interest in defining new parameters, novel indices and enhanced criteria, derived by the electrocardiograms during training, that would not only improve its sensitivity in diagnosis, but also add a prognostic branch to it.

2. ET as a diagnostic tool

2.1. ECG-derived indices beyond ST depression

2.1.1. Athens QRS score

One of the most revolutionary indices ever introduced in ET is "Athens QRS score". The whole conception of this index is attributed to an effort to increase the limited sensitivity of ST segment alternations during exercise to diagnose CHD. "Athens QRS Score" is based only to changes of Q, R and S waves during exercise, without implicating any ST segment changes. In order to calculate "Athens QRS Score", we subtract Q and S waves from the R wave in aVF and V5 leads at rest (standing position) and we sum the two values. In the same way, we subtract Q and S waves from the R wave in aVF and V5 leads at peak exercise (standing position) and we sum the two values: Athens QRS Score (mm) = (DR – DQ – DS) aVF + (DR – DQ – DS) V5 [3].

Changes of Q, R and S waves during exercise had been widely reported since 1990, but no one had ever created a complex metric system, implicating all these changes to one value, thus creating an index by which the false positive value of one of those wave changes could be compensated by the true positive values of the rest. So, Q-wave amplitude has been reported to remain unchanged or fail to increase in patients with CHD. This phenomenon has been attributed to an abnormal septal activation, reflecting loss of contraction associated with ischemia due to narrowing of the LAD [4]. R wave amplitude has been reported to remain unchanged or increase with exercise in patients with CHD. There are various physiological mechanisms associated with this alternation: a. increase in intracardiac blood, the so called "Brody Effect" [4], b. delay in intramyocardial

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conduction, caused by a progressive increase of the extra cellular potassium concentration in the ischemic myocardium [5], c. changes in heart rate, contractility and axis, and d. failure of the ischemic left ventricle to respond to adrenergic stimulation. Finally, S wave amplitude has been reported to increase both in normal subjects and in patients with CHD, but the magnitude of the increase in S wave amplitude is decreased in patients with CHD. This is not explained by the rightward and posterior axis shift observed in healthy subjects, but it is attributed to subendocardial ischemia [6].

"Athens QRS Score" achieved the disengagement of the ET from the strict boundaries of ST segment alternations during exercise, thus obliterating all limitations that this parameter contains. In this specific study conducted by our Department, with a prospective and a retrospective branch, "Athens QRS score" demonstrated a sensitivity of 75% and 86% and a specificity of 73% and 79% respectively for the detection of CHD, while "classical" ST segment changes had a sensitivity of 62% and specificity of 70%. Furthermore, it is directly associated with the number of the atheromatic vessels, with its value decreasing as the number of obstructed vessels in coronary angiography increases. The worth of this novel index is mostly eminent in those cases with false positive or inconclusive ETs (based on classical ST segment criteria). There are some limitations of the index, like existing left axis deviation, bundle branch blocks, left ventricular hypertrophy or intracardiac conduction abnormalities, restricting somewhat its applicability, but not at all diminishing its value in diagnosing ischemic heart disease through ET (Fig 1).

"Athens QRS Score" is directly related with ischemia during exercise rather than to just the number of the culprit coronary vessels. This was confirmed based on its better relationship with exercise-induced segmental contraction abnormalities on radionuclide ventriculography, or with exercise-induced reversible myocardial perfusion defects as defined by exercise Tl^{201} scintigraphy [7] (Fig 1).

"Athens QRS Score" has also been proved to increase the sensitivity and specificity of ET to heart patients after myocardial revascularization [8]. ETs conducted after 12 months of coronary artery bypass graft (CABG) or 6 months after percutaneous transluminal coronary angioplasty (PTCA) have clearly less reliability than the ETs before intervention [9]. This fact can be attributed to many different pathophysiological mechanisms: a. recessive limited area of viable myocardium, b. subcritical coronary stenosis, c. inappropriate constriction of small coronary vessels, d. decreased coronary flow reserve, e. persistent abnormal metabolic/functional state of the myocardium after coronary circulation restore, f. post-operating conduction abnormalities, g. regimen including digitalis or b-blockers, and h. inability of a patient to undergo exercise testing. "Athens score" seems to bypass the above limitations, significantly increasing the positive prognostic value of ET (Fig 1).

2.1.2. Prolongation of S wave

Besides "Athens QRS Score" and its derivatives, any type of alternations in ECGs during ET has also been studied in order to further improve the sensitivity and specificity of ET. In that way, it was feasible to establish signs of specific ischemic myocardial area, or, in other words, electrocardiographic signs attributed to ischemia by a specific coronary artery. In previous studies, it was shown that prolongation of S wave in lead V5 during exercise was indicative of LAD stenosis, but not of LCX or RCA [10,11], in cases that left anterior hemiblock (LAH) or right bundle branch block (RBBB) was recorded on ECG at rest [12]. Exercise-induced myocardial ischemia in the areas of the myocardium responsible for the development of the S wave decreases the conduction velocity in those areas (probably due to hyperkalemia, resulting from potassium extraction from the ischemic cells) and prolongs the duration of the S wave. These areas, in case of existent LAH or RBBB, receive blood supply mostly from LAD. This decreased conduction velocity is of great importance, since it may facilitate arrhythmias due to reentry.

2.2. ECG-derived indices linked to ST changes

ET has limited credibility in cases of 1 vessel disease [13]. Apart from the classical diagnostic criteria, other electrocardiographic criteria have been utilized to improve the sensitivity of exercise testing, such as the presence of inverted U waves, ST segment elevation (a non specific sign, also attributed to cardiac wall motion abnormalities, ventricular aneurisms or vasoconstriction) [14], ST spatial shift and the presence of R and/or S wave amplitude changes.

2.2.1. ST elevation in aVR, V1 and depression in V5

It is known that traditional evaluation of ST segment depression has not been useful for localizing the ischemic myocardium area supplied by the significantly narrowed coronary vessel [15]. ST segment elevation has been utilized for identifying ischemic regions in the past [16]. ST segment elevation can be attributed to various pathophysiological mechanisms: 1. subepicardial ischemia of a proximal myocardial segment, 2. subendocardial ischemia of a distal myocardial segment, and 3. factors not directly associated with

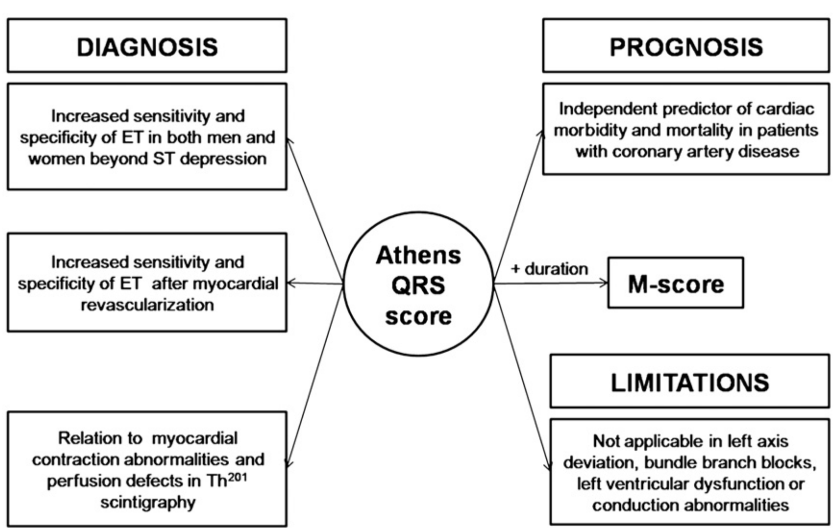

Fig. 1. Diagnostic, prognostic value and limitations of "Athens QRS score".