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Electrocardiogram Sensitivity in Left Ventricular Hypertrophy According to Gender and Cardiac Mass

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Abstract

Background: Several factors are known to interfere with electrocardiogram (ECG) sensitivity when diagnosing Left Ventricular Hypertrophy (LVH), with gender and cardiac mass being two of the most important ones.

Objective: To evaluate the influence of gender on the sensitivity of some of the criteria used to detect LVH, according to the progression of ventricular hypertrophy degree.

Methods: According to gender and the degree of LVH at the echocardiogram, the patients were divided in three groups: mild, moderate and severe LVH. ECG sensitivity to detect LVH was assessed between men and women, according to the LVH degree.

Results: Of the 874 patients, 265 were males (30.3%) and 609, females (69.7%). The [(S + R) X QRS], Sokolow-Lyon, Romhilt-Estes, Perugia and strain criteria showed high discriminatory power in the diagnosis of LVH between men and women in the three groups with LVH, with a superior performance in the male population and highlighting the importance of the [(S + R) X QRS] and Perugia scores.

Conclusion: The diagnostic sensitivity of the ECG increases with the cardiac mass, The examination is more sensitive in men. highlighting the importance of the [(S + R) X QRS] and Perugia scores. (Arq Bras Cardiol 2011; 97(3) : 225-231)

Keywords: Electrocardiography; hypertrophy. left ventricular; hypertension; heart failure. gender identify.

Introduction

Left Ventricular Hypertrophy (LVH) is an independent predictor of morbimortality in the general population when diagnosed by either the ECG or the echocardiogram[1,2].

Since the pioneer observations of the Framingham Heart Study, several epidemiological studies have highlighted LVH as one of the most important risk factors for angina pectoris, myocardial infarction, heart failure, cerebrovascular accident and sudden death[3].

Among the several propaedeutic methods for the diagnosis of LVH, the least expensive, most broadly disseminated and easier to interpret method is the electrocardiogram (ECG), which presents high specificity, although it has low diagnosis sensitivity. However, in spite of this limitation, it remains a broadly used complementary test in medical practice as well as in population studies, in the prevention as well as in the analysis of regression of the hypertrophic process[3,4]. Additionally, the ECG has excellent reproducibility, being very useful in the clinical follow-up of the patients.

Some situations can alter the ECG sensitivity in the LVH diagnosis, with gender being one of the most important[5-7].

The objective of the present study was to assess the influence of gender on the sensitivity of some criteria used for LVH detection, according to the progression of the ventricular hypertrophy degree.

Methods

From March 2006 to December 2009, 12-lead electrocardiograms of 874 hypertensive patients that were followed at the outpatient clinic and regularly used anti-hypertensive medication were analyzed. Patients that had orovalvular disease, acute or chronic coronary artery disease, previous myocardial infarction, Chagas' disease, rhythm disorders, bundle branch blocks, used digitalis, had ventricular pre-excitation syndrome, patients with large left ventricular (LV) masses and those with inadequate technical quality of the echocardiogram or any other condition that could potentially distort the LV geometry and the electrocardiographic analysis, were excluded.

The study protocol was approved by the Ethics Committee in Research of Universidade Federal de São Paulo - Escola Paulista de Medicina (Unifesp-EPM).

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Electrocardiogram

The resting ECG was carried out with the patient in the supine position, obtaining the 12-lead electrocardiogram with a velocity of 25 mm/s, standard calibration for 1.0 mV/cm (Dixtal EP3 equipment, Brazil). The ECG tracing was decoded and, for the analysis of several variables, a magnifying lens that allowed a magnification of 5x on its contact surface with the tracing was used, to obtain higher precision in the analysis. The QRS complex axis and duration, the R-wave amplitude in leads D1, aVL, V5 and V6, the S-wave amplitude in V1, V2 and V3, the strain pattern in V5 and V6, as well as a higher amplitude of the R and S waves in the horizontal plane leads were quantified by the same observer, a very experienced cardiologist. Eight LVH electrocardiographic criteria were separately analyzed.

1. Higher S + higher R in the horizontal plane multiplied by the longest duration of QRS [(S + R) X QRS]: addition of higher amplitude of S wave with the higher amplitude of R wave in the horizontal plane (em mm), multiplying the total by the duration of the QRS complex (in seconds), where the latter is the broadest, normally in leads V_2 or V_3. The LVH score by the ECG is defined when the result is $\geq$ 2.8 mm.s[8].

2. Sokolow-Lyon voltage criterion: $SV_1 + RV_5$ or $V_6 \geq$ 35 mm[9].

3. Cornell voltage criterion: $RaV_L + SV_3 \geq$ 20 mm for women and $\geq$ 28 mm for men[10].

4. Cornell duration criterion: $(RaV_L + SV_3)$ X QRS duration; for women, add 8 mm, $\geq$ 2440 mm.ms[11].

5. Romhilt-Estes score: higher amplitude of R or S $\geq$ 30 mm in the horizontal plane or $\geq$ 20 mm in the frontal plane or strain pattern *in* V_5 or V_6 (when using digital it is worth only one point) or left atrial enlargement by the Morris index (three points); ÂQRS electrical axis > -30 degrees (two points); QRS duration $\geq$ 90 ms in V_5 or V_6 or ventricular activation time $\geq$ 50 ms in V_5 or V_6 (one point). Using this score, LVH is diagnosed when the score $\geq$ 5 points[12].

6. R wave of $aV_L \geq$ 11 mm[13].

7. Perugia score: LVH is diagnosed by the presence of one or more of the following findings: Cornell criteria, considering the limit for women $\geq$ 20 mm and for men $\geq$ 24 mm, Romhilt-Estes score and strain pattern[14].

8. Presence of strain pattern: defined as a convex depression of ST segment with asymmetric inversion of T wave opposed to the QRS complex in leads V_5 or V_6[5].

The analysis of method reproducibility was carried out by three observers that independently interpreted 100 ECG tracings randomly removed for analysis of the amplitude of the R and S waves and QRS complex duration.

Transthoracic Echocardiogram

The examinations were carried out at the Doppler Echocardiography Service of Unifesp-EPM (ATL 1500 equipment, USA), with de 2.0 and 3.5 MHz transducers. The patient was positioned in left lateral decubitus and the images were obtained from the left parasternal region between the fourth or fifth intercostal space and the usual slices were performed to carry out the complete study in M-mode and two-dimensional mode, simultaneously to the ECG registry. According to the recommendations of the Penn Convention, the following measurements were obtained: LV size in systole and diastole; thickness of the interventricular septum and LV posterior wall at the end of the diastole, left ventricular-end diastolic and systolic volume, percentage of diastolic shortening and ejection fraction by the cube method. LV mass was calculated by the formula: LV mass = 0.8 X {1.04 [(IVSD + LVEDD + LVPWD)^3 – (LVEDD)^3]} + 0,6 g[15], where IVSD is the interventricular septum in diastole, LVEDD is the left ventricular end-diastolic diameter and LVPWD is the LV posterior wall in diastole. The LV mass was indexed for body surface area to adjust for differences in heart size according to the patient's size. Body surface was calculated by the formula: BS = (W – 60) X 0.01 + H, where BS is the body surface in m^2, W is the weight in Kg and H is height in meters[16]. Body Mass Index (BMI) was calculated by dividing the weight (Kg) by the square height (m). The patients were divided by gender and degree of ventricular hypertrophy, calculated by the echocardiogram, according to the recommendations of the American Society of Echocardiography/European Association of Echocardiography[17], as summarized in Table 1. Thus, mild LVH was considered, for the female population, when the LVMI was 89-100 g/m^2; moderate LVH with LVMI of 101-112 g/m^2 and severe LVH with LVMI > 113 g/m^2. For the male population, these values were 103-116 g/m^2; 117-130 g/m^2 and > 131 g/m^2, respectively. The study of diagnostic sensitivity was carried out in the eight ECG methods evaluated herein, with the three degrees of hypertrophy described, always comparing the results obtained between men and women.

Statistical Analysis

Continuous variables were expressed as means and standard deviations. Categorical variables were expressed as percentages. All significance probabilities (p values) are two-tailed. Sensitivity values were estimated in each one of two independent samples and then compared using Fisher Exact Test. Kappa test was used for the reproducibility study[18]. In this test, values > 0.75 are considered excellent ones; values < 0.40 are considered as poor concordance and those between 0.40 and 0.75 as good concordance. Statistical significance was verified in all comparisons by using 95% confidence intervals and a p value < 0.05.

Results

Of the 874 patients included in the study, all with LVH identified by echocardiography, 265 were males (30.3%) and 609 were females (69.7%), with a mean age of 59.7 $\pm$ 10.8 years. Table 1 shows the distribution by gender and by LVH degree, as well as the general characteristics of the studied sample.

Regarding the sensitivity values, it can be observed that for almost all of them, the electrocardiographic criteria are more effective in diagnosing LVH in the male population, except for the Cornell voltage criteria, which was the only one with a better performance among female individuals in the three degrees of LVH, although statistically significant

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only in the group with severe LVH. Only the [(S + R) X QRS] and Cornell voltage criteria showed progressive sensitivity percentages according to the increase in LVH degree. In the studied population, the [(S + R) X QRS], Sokolow-Lyon, Romhilt-Estes, Perugia and strain pattern criteria showed high discriminatory power in the diagnosis of LVH between men and women in the three degrees of hypertrophy, with a much superior performance in the male population and highlighting the [(S + R) X QRS] and Perugia scores, as shown in Table 2.

As for the reproducibility study, the level of concordance among the three observers varied from 0.82 to 0.98, and were considered excellent. The first value corresponds to the QRS complex and the last to the amplitude of R and S waves.

Figure 1 illustrates an ECG tracing of a patient from the present sample, which has all other electrocardiographic criteria of LVH studied herein, except for the criterion R of aVL ≥ 11 mm. Figure 2 shows the M-mode echocardiogram of the same patient, disclosing the three variables used for the calculation of LV mass. The interval between the examinations was 25 days.

Discussion

The influence of gender and LV mass increase on the diagnostic sensitivity of the ECG in relation to LVH is clear.

LVH is a marker of high cardiovascular risk, regardless of comorbidities, with no difference regarding ethnicity, presence or absence of systemic arterial hypertension or coronary disease, in both clinical and epidemiological studies, with a close association between LVH and adverse cardiovascular events. Hence, the importance of its detection by low-cost and easy-to-apply diagnostic methods in large populations, as well as the knowledge of interference in specific populations, as in the case of the male and female genders, the obese, the elderly and smokers[6,19-21].

The LVH usually leads to an increase in the QRS complex amplitude, and, consequently, the electrical forces shift to the left and posteriorly, originating deep S waves in the right precordial leads. On the other hand, the higher transverse ventricular activation, a result of the LVH, causes an increase in QRS duration and intrinsicoid deflection (the interval from the earliest onset to the peak of the QRS complex in the left precordial leads)[3,5].

The present study used the transthoracic echocardiogram as a reference for the diagnosis of LVH. The modified Devereux formula[15] has good correlation with the left ventricular mass in necropsy studies (r = 0.90; p < 0.001) and applies to normal geometry ventricles, considered to be ellipsoid and within standards that allow volume extrapolation by the cube formula. In spite of the undeniable contribution of the echocardiogram in the diagnosis and knowledge of LVH, its cost is much higher than that of the ECG, in addition to its methodological limitations regarding reproducibility, as it depends greatly on the observer, a fact that limits its use in epidemiological studies[8].

As mentioned before, it is known that the electrocardiographic diagnosis of LVH is influenced by some factors, such as age, obesity, tobacco smoking and gender[6], with the latter being of the object of the present study. Levy et al[6] demonstrated, in patients from the Framingham Heart Study, that the prevalence of LVH was higher in women than in men at the echocardiographic study, a finding that was not confirmed at the ECG (women = 5.6%; men = 9.0%; p = 0.075).

Regarding the present sample, the patients were divided by gender and by progressive degrees of LVH. It is common knowledge that the ECG is an examination with high specificity and low sensitivity in the detection of LV in the general population of individuals with hypertrophic hearts. However, the accuracy behavior of this method with crescent degrees of left ventricular mass remains unknown, a fact that is very important considering that the myocardial cell hypertrophy increases the muscle mass globally, although that does not necessarily mean a higher electrical potential generation. In fact, this contradiction between a hypertrophied LV and the absence of QRS complex increment can be justified by a higher amount of collagen fibers in the heart. These fibers develop in parallel to the LVH process. As a result, there is an isolation of cardiac fibers, with consequent ischemia, cell death and substitutive repair by more collagen tissue. Hence, although the heart shows an increased mass, its capacity to generate electrical potential can be even decreased[22-24]. It is noteworthy the fact that the variables age, body surface and body mass index were very similar in both genders, which practically excludes the interference of these factors on LVMI.

Okin et al[25], in a study with 389 patients, of which 116 had LVH, suggested that the worse performance of the ECG in women might be partially attributed to the lower voltage and duration of QRS complexes, due to the differences in body surface and heart dimensions observed between the genders. On the other hand,

Table 1 – Characteristics of the studied population by gender and LVH degree

Variable	Mild LVH (n=321)		Moderate LVH (n=216)		Severe LVH (n=337)	
	M	F	M	F	M	F
Gender (n)	89	232	60	156	116	221
Age (years)	59.2 ± 11.4	58.6 ± 10.4	60.4 ± 10.6	60.6 ± 9.5	61.1 ± 11.0	59.9 ± 11.6
BS (m^2)	1.8 ± 0.1	1.6 ± 0.1	1.8 ± 0.1	1.6 ± 0.1	1.7 ± 0.1	1.6 ± 0.1
BMI	27.2 ± 6.3	28.4 ± 5.3	26.2 ± 3.8	28.3 ± 5.3	25.6 ± 3.4	28.0 ± 5.2
LVMI (g/m^2)	109.3*	93.7*	123.9*	106.4*	153.4*	128.5*

*Median; LVH - left ventricular hypertrophy; M - male; F - female; BS - body surface; BMI - body mass index; LVMI - left ventricular mass index.
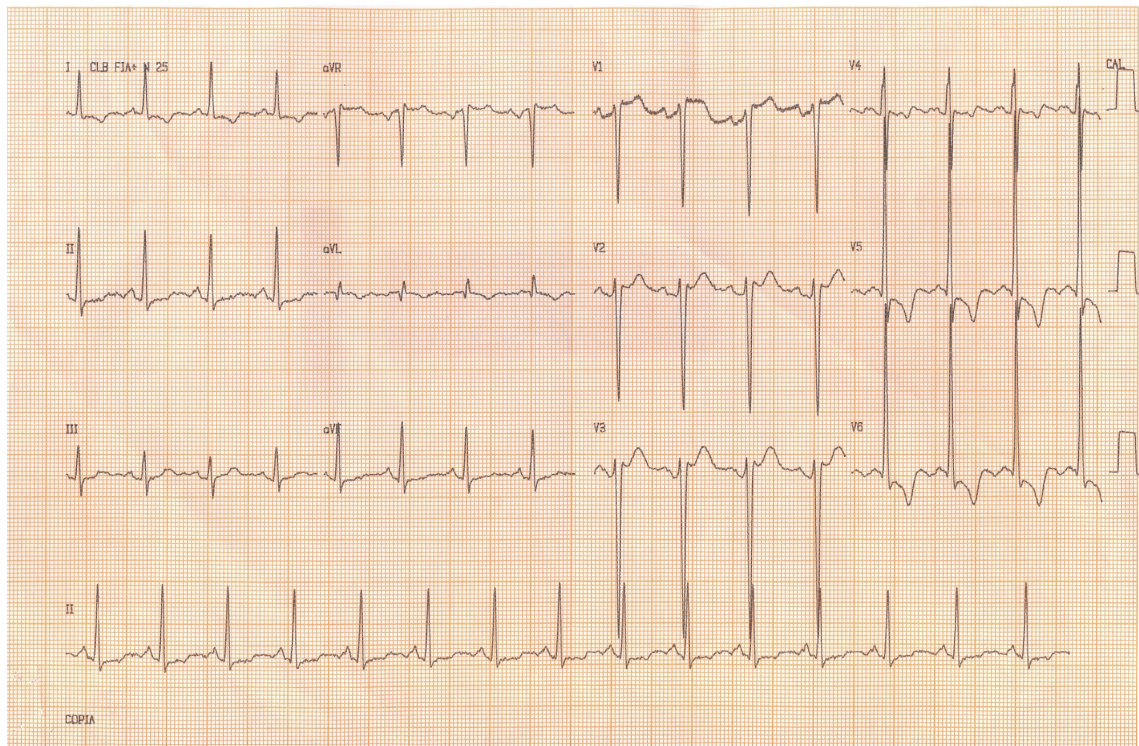
Figure 1 – *ECG of 51-year-old female patient with stage-3 arterial hypertension. Except for R of aVL ≥ 11 criterion, all other assessed criteria are present.*
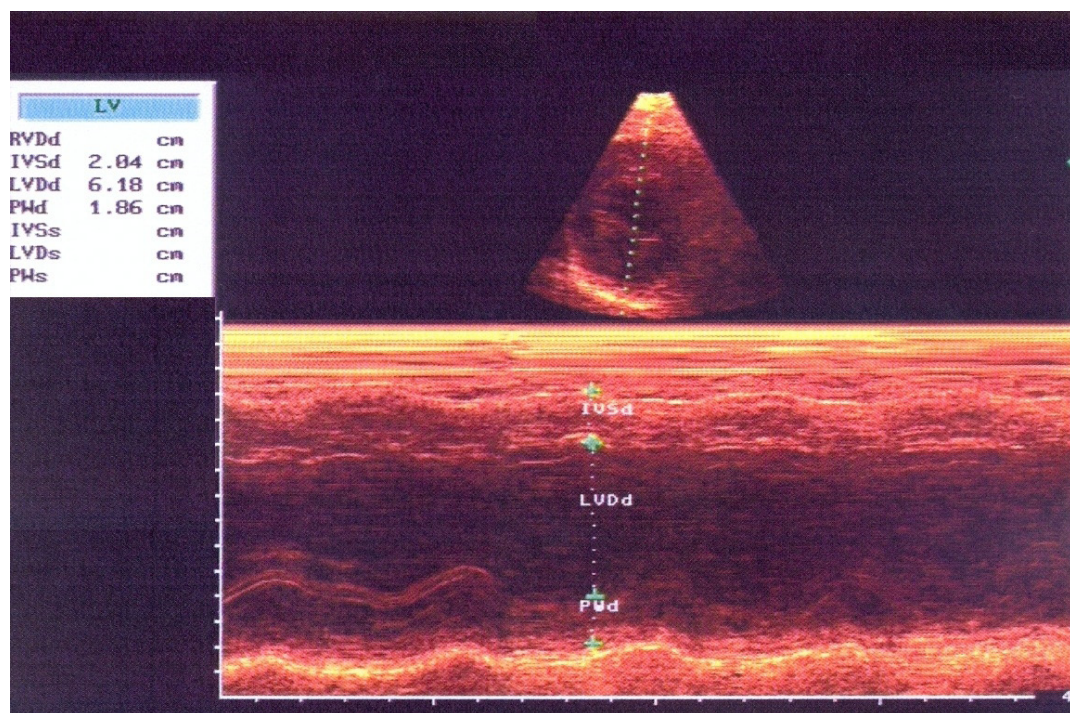

Figure 2 – *M-mode echocardiogram of the same patient. The three variables used to calculate the left ventricular mass are shown: IVS = 20.4 mm; LVPW = 18.6 mm and LVDd = 61.8 mm; (LVMI = 385.5 g/m2).*

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Table 2 – Comparison of diagnostic sensitivity of ECG in the study of LVH between men and women, according to the increase in myocardial mass

Criterion ECG / LVH degree	[(S + R) X QRS] M % (IC)	F % (IC)	Sokolow-Lyon M % (IC)	F % (IC)	Cornell voltage M % (IC)	F % (IC)	Cornell duration M % (IC)	F % (IC)	Romhilt-Estes M % (IC)	F % (IC)	RaVL M % (IC)	F % (IC)	Perugia M % (IC)	F % (IC)	Strain M % (IC)	F % (IC)
Mild LVH	35.9 (26.0/46.8)	11.1 (7.4/15.9)	11.2 (5.5/19.6)	3.8 (1.7/7.2)	5.6 (1.8/12.6)	9.4 (6.0/13.9)	7.8 (3.2/15.5)	3.0 (1.2/6.0)	12.3 (6.3/21.0)	3.4 (1.4/6.6)	6.7 (2.5/14.1)	5.1 (2.6/8.8)	25.8 (17.1/36.2)	14.5 (10.3/19.7)	17.9 (10.6/27.5)	6.8 (3.9/10.9)
p	<0.0001		0.017		0.3692		0.0686		0.0232		0.5918		0.0223		0.0057	
Moderate LVH	48.3 (35.2/61.6)	15.3 (10.1/22.0)	15.0 (7.1/26.5)	3.8 (1.4/8.1)	6.6 (1.8/16.2)	12.8 (8.0/19.1)	16.6 (8.2/28.5)	2.5 (0.7/6.4)	21.6 (12.0/34.2)	2.5 (0.7/6.4)	13.3 (5.9/24.5)	3.8 (1.4/8.1)	33.3 (21.6/46.6)	13.4 (8.5/19.8)	21.6 (12.0/34.2)	5.7 (2.6/10.6)
p	<0.0001		0.0069		0.2349		<0.0001		<0.0001		0.0253		0.0016		0.0016	
Severe LVH	76.0 (67.3/83.4)	40.0 (33.5/46.8)	31.6 (23.3/40.8)	19.3 (14.3/25.1)	11.9 (6.7/19.2)	38.2 (31.8/45.0)	20.5 (13.6/28.9)	18.0 (13.2/23.7)	37.6 (28.8/47.0)	14.8 (10.4/20.2)	17.0 (10.7/25.1)	18.0 (13.2/23.7)	65.8 (56.4/74.3)	45.0 (38.3/51.8)	41.8 (32.8/51.3)	22.0 (16.8/28.1)
p	<0.0001		0.0152		<0.0001		0.6616		<0.0001		0.8819		<0.0001		<0.0001	

ECG - electrocardiogram; LVH - left ventricular hypertrophy; M - male; F - female; CI - confidence interval.

it is known that the left ventricular mass indexation practically eliminates this problem[15].

At the study of diagnostic sensitivity of the ECG, the objective of the present study, one can observe an excellent performance of the [(S + R) X QRS], Sokolow-Lyon voltage, Romhilt-Estes, Perugia and strain pattern criteria, mainly with the progression of the hypertrophy degree, confirming that the ECG is more effective in diagnosing LVH in the male population, perhaps a reflection of the higher QRS complex expression (amplitude and duration) in male individuals[24]. In opposition to this logic, the exception was the Cornell voltage criteria, which, regarding the three degrees of LVH, had its best performance in females, although showing statistical significance only in the group with severe LVH.

Alfakih et al[7], in a study that evaluated three of the methods assessed here, having magnetic nuclear resonance as the reference standard for comparison of LVH, demonstrated that the Cornell voltage and duration criteria were more effective in diagnosing LVH in male individuals, whereas the Sokolow-Lyon product criterion was superior in the female population. Costa et al[26], studying patients with chronic kidney disease stage 5, whose prevalence of LVH was 83% and mean LVMI of 154.9 ± 57.3 g/m^2, also showed that the Sokolow-Lyon voltage, Sokolow-Lyon product, Cornell voltage, Cornell product and Romhilt-Estes criteria diagnosed more LVH in the male population.

In the present study, the evaluation of the [(S + R) X QRS] score, which, in the original study that presented this new score with 1,204 controlled hypertensive patients, found a sensibility of 35.2% and a specificity of 88.7% for the diagnosis of LVH also showed good sensitivity, especially in the male population. This criterion, which uses the sum of the highest R wave and the highest S wave in the horizontal plane, multiplied by a higher duration of the QRS complex, has a consistent basis from the physical point of view, as the relation of increased electrical activity in LVH is shown by a spatial vector that has amplitude and duration. The higher expression of the R and S waves and the QRS complex represented by this vector showed good correlation with left ventricular mass[8].

One can conclude, based on the present series, that the ECG show better performance in the diagnosis of LVH as the LV mass increases. One can also conclude that, for any degree of LVH, the ECG is, in general, more sensitive to attain the diagnosis in the male sex. In this same population, the [(S + R) X QRS] and Perugia scores presented better sensitivity in the sample studied herein.

Potential Conflict of Interest

No potential conflict of interest relevant to this article was reported.

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Study Association

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