Gac Méd Caracas 2022;130(4):685-695
DOI: 10.47307/GMC.2022.130.4.2

Electrocardiographic index in aortic root enlargements and ventricular hypertrophy with Phi-based chest-wall thickness derived measure

Índice electrocardiográfico en la dilatación de la raíz aórtica e hipertrofia ventricular y una medida derivada del grosor de la pared torácica basada en Phi

José Ramón Lanz-Luces[1a], Fernando Augusto Alves da Costa[2b], Luís Fernando Escobar Guzman[2c], Juan de Dios Amachuy Alaca[3a]

SUMMARY

Introduction: *In addition to left ventricular hypertrophy (LVH), dilated aortic root (DAo) is a risk factor for cardiovascular events. There is a lack of a practical index that considers both scenarios.* **Objective:** *To assess an electrocardiographic index in DAo and LVH considering echocardiographic guidelines and those values stemming from the chest wall thickness (CT).* **Methodology:** *The population was 631 patients, 236 hypertensives (HT) and 395 non-hypertensives (NHT), the diameter of the aortic root was based on the Phi number and a derived formula CT x 1.33 = Ao, using a cut-off >15 %. The index stemmed from the R + S amplitude sum in leads D1 + D2 + D3 and values <23mm. We compared additionally Cornell and Sokolow-Lyon-Rappaport indexes with guidelines criteria for DAo and LVH, using univariate and multivariate statistics.* **Results:** *The index prevalence was similar between groups (p=0.15). There were group differences in the aorta, septum, posterior wall, and ventricular mass (p<0.05). The index failed to discriminate LVH, on the contrary, it was DAo associated based on CT (OR: 2.058 CI95 %: 1.442-2.938, p<0.001) for the general population and in NTH (OR: 2.911 CI95:1.782-4.755, p<0.001). Still, in NTH the index was associated with DAo guidelines (OR:2.758 CI95 %:1.002-7.594, p=0.042). Cornell index showed similar odds, however, with less sensibility than the novel index. In the regression analysis, we found a positive relationship (R=0.573), between the aorta and independent variables: sex, novel index, and BSA.* **Conclusion:** *This index was advantageous in separating those with DAo based on the ET formula, as well as by consensus in non-hypertensive patients.*

Keywords: *Aortic root enlargement, left ventricular hypertrophy, electrocardiographic index, golden number, Phi.*

DOI: https://doi.org/10.47307/GMC.2022.130.4.2

ORCID: 0000-0003-2252-2435[1a]
ORCID: 0000-0003-2460-7651[2b]
ORCID: 0000-0003-0515-4108[2c]
ORCID: 0000-0002-9216-9449[3a]

[1] MD, PhD in Cardiology – Research Assistant- Instituto Paulista de Doenças Cardiovasculares (IDPC). São Paulo - SP, Brasil.
[2] MD, PhD in Cardiology - Hospital Beneficência Portuguesa de São Paulo. São Paulo - SP, Brasil.
[3] MD, Cardiology- Clínica J Cor, Rua Orense, 41-Sala 1202-Centro-Diadema, São Paulo, Brasil.

Correspondent author: José Ramón Lanz-Luces.
E-mail: jrlanz64@protonmail.com

Recibido: 10 de agosto 2022
Aceptado: 3 de octubre 2022

RESUMEN

Introducción: *Además de la hipertrofia ventricular izquierda (HVI), la dilatación de la raíz aórtica (DAo) es factor de riesgo para eventos cardiovasculares. No se tiene un índice práctico que contemple ambos escenarios.* **Objetivo***: Evaluar un índice electrocardiográfico en la HVI y en la DAo considerando directrices y de valores derivados de la espesura torácica (ET).* **Metodología***: Se emplearon 631 pacientes, 236 hipertensos (HT) y 395 no hipertensos (NHT), el diámetro de la raíz aórtica se basó en el número Phi y fórmula derivada ET x 1,33 = Ao, utilizando un punto de corte >15 %. El índice suma amplitudes R + S en D1 + D2 + D3, presente si < 23 mm. Adicionalmente se evaluaron los índices de Cornell y Sokolow-Lyon-Rappaport, usando pruebas estadísticas univariadas y multivariadas.* **Resultados:** *Hubo diferencias grupales en aorta, septo, pared posterior y masa ventricular (p<0,05). La prevalencia del índice fue similar entre grupos (p = 0,15). No hubo asociación con HVI y si con DAo calculada en la población general (OR: 2,058 CI95 %:1,442-2,938, p<0,001) y en NHT (OR: 2,911 IC95:1,782-4,755, p<0.001). También en NTH el índice estuvo asociado a DAo basado en directrices (OR:2,758 CI95 %:1,002-7,594, p=0,042). El índice de Cornell mostró probabilidades similares, aunque, menor sensibilidad en relación con el nuevo índice. En la regresión encontramos relación positiva (R=0,573), entre la aorta y variables independientes: sexo, valores del índice y superficie corpórea (SC).* **Conclusión:** *Este índice fue ventajoso en separar aquellos con DAo basada en la fórmula de la ET, al igual que por consenso en pacientes no hipertensos.*

Palabras clave: *Dilatación de la raíz aórtica, hipertrofia ventricular izquierda, índice electrocardiográfico, numero áureo, Phi.*

INTRODUCTION

Long-term hypertension exerts alterations both in the left ventricle size and in its continuation, the aorta (1). The ventricular mass increase is associated with DAo, a marker for subclinical left ventricular diastolic dysfunction (2). According to some authors, LVH is a standalone predictor of acute cerebrovascular events in hypertensive patients (3), with prognostic implications for morbidity and mortality after myocardial infarction (4). Elderly patients with non-dialytic renal failure who have LVH also have a faster decrease in renal function (5).

Additionally, increased ventricular mass in long-term followed-up patients is a sudden death-related cause (6), with a reported risk of 2.29 (CI 95 % 1.1-4.74, p = 0.026) for patients with values greater than 120 g/m^2. In another contiguous scenario, DAo leads to associated rises in mortality, it has been the 13th cause of death in Western countries (7). Moreover, aorta enlargement is correlated with various risk factors, including age (8), smoking, obesity, and hypertension (9), the latter factor being the most prevalent in vessel dissection (10).

Electrocardiographically, some attempts have been made to correlate left ventricular hypertrophy with echocardiographic measurements without much success. It is difficult to find the presence of a hypertrophy marker index, such as the Sokolow index, in patients with minor non-echocardiographic alterations. However, some applicability described appears to only benefits obese patients (11). Other authors also observed sex differences. In a study evaluating Sokolow-Lyon-Rappaport and Cornell indexes, the first had greater sensitivity to detect LVH in men but the second index was better in women (12). On the other hand, there is no known electrocardiographic index predicting DAo in the literature.

Acknowledging the cardiovascular risks entailed sparked a need to relate to or predict these pathologies. We foresee that aim using low-cost tools, such as the electrocardiogram, in a neoteric assessment, thanks to a novel calculus based on the golden number (a universal pattern) and the CT.

Subject and Methods

This cross-sectional study compared ECG and echocardiograms in 631 patients, HT: n=236 and NHT: n=395, from a database of Institutional ambulatory patients, in São Paulo, Brazil. Patients without hypertension were referred to the institution as part of the cardiologic evaluation to keep routine exercises (recreational sports, not competitive). Those patients were asymptomatic and healthy. Hypertension was defined if the patient presented blood pressure above 140/90 mmHg or in chronic specific treatment. Pathologies that could influence aortic root diameter were considered exclusion criteria (bicuspid aorta, Loeys-Dietz syndrome, Ehler-Danlos syndrome, syphilis, tuberculosis, ankylosing spondylitis, Takayasu arteritis, giant cells arteritis, smoking). Additionally, other exclusion causes were those that could modify electrocardiographic criteria for left ventricular hypertrophy such as athletic hypertrophy due to its controversial results (13,14), stenotic valve disease (15), hypertrophic cardiomyopathy, and congenital heart disease. ECG recordings with complete bundle branch block, myocardial infarction, Wolff-Parkinson-White syndrome, atrial fibrillation, and digitalis used were also excluded. Overweight and obesity were included but not patients with body mass index (BMI) above 40 or less than 18.

Echocardiographic assessment

Echocardiography was performed with the Toshiba Nemio 30 Ultrasound System (Otawara-Shi, Tochigi, Japan), equipped with a 2.5 - to 5.0-MHz multifrequency transducer. The patients were positioned in a left lateral decubitus for image acquisition in the parasternal and apical views. During the exam, heart rhythm and frequency were monitored using an electrocardiographic lead. All heart structures were measured according to the American Society of Echocardiography (ASE) and the European Association of Cardiovascular Imaging (EACVI) updated recommendations (16). The exams were performed by an observer and immediately reviewed by another, who was blind to the first assessment.

Electrocardiogram assessment

A resting 12-Lead ECG was performed using an HP page writer 200i machine. All the tests were performed and analyzed at the Service of Electrocardiography in the same Institute.

Phi-derived measures

A dichotomization of the population was created, using a cut-off level diagnosing increased aortic root diameter greater than 15 % based on the value of Macruz' hypothesized formula: CT x 1.33 = AoD. The golden number (Phi) core association is based on hemodynamic studies where CT is lineally related to central venous pressure and can predict in subjects with height/weight proportion in all cardiac chambers. The author was based on a general formula (ET=high(meters/8), being 8 part of the Fibonacci sequence and a simplification formula Phi number related (17).

CT corresponds to the thoracic thickness or anteroposterior chest diameter that could be also a theoretical biometric equation (height 1/5) * 0.618≈(Phi), in an individual who has an ideal proportion between height and weight. To our best knowledge. the abovementioned formula has not been described or tested in any other author's research. Our pivotal electrocardiographic measure was the sum of the R+S amplitude in leads D1+D2+D3 (hereby ascribed by us as a novel index). The 15 % used in our calculus was considered a mild difference between groups but an acceptable margin similar to those used in non-inferiority trials (18).

We considered the index presence if the vectors sum <23 mm, after observing matched the frequency distribution's mean value in this population. These three vectors or electrocardiography derivations were chosen mainly because they represent the outlier components of Eithoven's triangle, known as the Standard limb leads. Those values were compared with echocardiographic root aortic limits for DAo and LVH. Regarding electrocardiography measures, the Sokolow-Lyon-Rappaport criteria were used, where the sum of the S amplitude in lead V1 with the R wave in the lead where it is greater (V5 or V6) is used, being classified as positive if the sum were equal to/or higher than 35 mm. Additionally, we also studied the Cornell voltage criteria, which consists of the R wave in AVL with the R wave of lead V3 sum, and values >28 mm for males and >24 mm for females.

Our reference for LVH diagnosis was throughout the echocardiogram. The ventricular mass calculation was sex-based and used join guidelines from the American Society of Echocardiography and the European Association of Echocardiography (16), where the defined LVH value was indexed by BSA (> 95 g/m^2 for women and >115 g/m^2 for men). An increase in the diameter of the aortic root was considered if the root diameter was >37 mm in men or >35 mm in women, corresponding to values above the 95 % percentile in accordance with a normality local population study (19). Studies on the diameter of the aorta indexed by BSA determine to limit values for those greater than 2.1 cm/m^2, (20). Further authors included sex, age, and BSA in the formula (21).

Statistical analysis

"The *a priori* sample size calculation was performed using the G * Power program version 3.1.9.7 (Heinrich Heine University, Düsseldorf, Germany) for the CH^2 test, considering a statistical power of 90 % and an error $\alpha = 0.05$. The minimum sample size was 183. The Kolmogorov-Smirnov test determined data normality helping gauge and remove atypical records from the main variables (aortic root diameter, left ventricular mass, and ECG index scores). The continuous variables were expressed as mean and standard deviation and accounted for as percentages if they were categorical variables. We analyzed categorical variables by the Chi^2 method and if necessary, using Fisher's correction. Continuous variables were analyzed by the Student T-test. A multiple regression analysis was used to estimate how the aortic root diameter is related to the chosen independent variables, previous univariate analysis. Data were evaluated using the IBM Corp. Released 2015. IBM Statistics SPSS Statistics for Windows, Version 23.0. Armonk, NY: IBM Corp program. All tests were two-tailed.

Ethical issues

The ethical standards legislated by the Declaration of Helsinki, based on guidance and the principles of the World Medical Association, including its last amendment by the 64th WMA General Assembly, Fortaleza, Brazil, October 2013, aimed the research. The research institution approved the study protocol and did not interfere with any medical prescription, recommendations, or other protocols that could be part of the health center.

RESULTS

The total population of adults admitted was n=631, however, 25 patients were out of the analysis because been outliers. The remaining patients (n=606) encircled two hundred twenty-eight hypertensives (37.6 %) and three hundred seventy-eight non-hypertensive cases (62.4 %). Concerning the novel index presence, although importantly present (n=364, 60.1 %) in the population, the only echocardiographic measurements that differed were the root aortic diameter and the atrium-aorta ratio. No significant difference was observed between HT (60.2 %) vs. NHT (39.82 %), p=0.168, and the ECG index presence. Otherwise, if present, variations in root aortic diameter were observed (31.65±3.80 mm vs 30.91±3.60 mm, p=0.018), Table 1.

Notably, the mean value for the relationship between diastolic and systolic left ventricular ratio was near the PHI number≈1.618... for both groups, with and without the novel index (Table 1).

Thirty-eight participants had DAo by consensus values, but the EKG index was present in 24 of them and had no statistical significance in the general population (p=0.688). Interestingly, when the population was divided, we found a difference in each group regarding predicted positive values, and similar outcomes for accuracy and negative predictive values (Table 2). However, using the CT formula, the index presence was linked to a >15 % increase in predicted aortic root diameter (OR: 2.189 CI 95%:1.546-3.100, p<0.001). Moreover, the cases spotted by the index were more than six times those detected by consensus guidelines, Table 2.

We found only 103 patients that met the echocardiographic criteria for LVH. There was no correlation between this criterion and the new index. The Sokolow-Lyon-Rappaport index behaved in a similar manner (Table 3). Moreover, the Cornell index is thus significantly different between the population and in the hypertensive group, it gathered few cases for ventricular hypertrophy (Table 4).

Table 1. Electrocardiographic index (DI+DII+DIII) and echocardiogram measures

	EKG index (DI+DII+DIII)		
	Present n=364	Absent n=242	p
Aorta (mm)	31.65 ± 3.80	30.91 ± 3.60	0.018
Left atrium (mm)	33.25 ± 4.13	33.76 ± 4.01	0.132
LV in diastole (mm)	48.16 ± 3.60	47.99 ± 4.00	0.598
LV in systole (mm)	29.92 ± 3.03	29.86 ± 3.50	0.800
Septum	8.22 ± 1.00	8.19 ± 1.03	0.712
Posterior wall	8.06 ± 0.93	8.05 ± 0. 94	0.931
LV mass (g)	165 ± 37	164 ± 38	0.727
LV mass/BSA (g/m^2)	90.0 ± 17	88.0 ± 18	0.114
Ao/LA ratio	1.06 ± 0.8	1.14 ± 0.1	<0.001
LV Diastolic/systolic ratio	1.616 ± 0.1	1.615 ± 0.1	0.966

LV: Left ventricle, LA: left atrium, BSA: body surface area.

Aside from finding that the novel index was more prevalent in those with altered DAo based on the CT equation, we discovered a favorable 70.68 % test sensibility but a lesser specificity (40.14 %). The NHT group presented similar results (sensibility: 72.28 %, specificity: 23.56 %). Furthermore, the odds of a subject having the index and >15 % difference of its aorta root diameter based on CT were 2.058 CI 95%: 1.442-2.938.

Additionally, the index was more prevalent in NHT patients, with an aortic diameter above normal by consensus (Table 2), resulting in an OR:2.758 CI 95%:1.002-7.594, p<0.042. In hypertensive patients, most of the patients lack having DAo by consensus; 93.4 %, n=213. From those who had it, the index was present in a few of them (6 within the novel index and 9 without it, Table 2). Despite a p<0.05, the result led to a loss of association between the exposure and the outcome because an OD: 0.355 CI 95%: 0.122-1.036.

Concerning dilated aorta based on guidelines, we also found significant and opposite differences between groups and not when the general population was analyzed. Nonetheless, the results of predictive positive and negative values were similar, Table 2.

Table 2. Electrocardiographic index, ventricular hypertrophy, and aortic root enlargement

	ELECTROCARDIOGRAPHIC INDEX N=364							
	Present	Absent	P	Sen	Esp	PPV	NPV	ACC
GP								
DAo C	24 (63.2 %)	14 (36.8 %)	0.688	63.16	40.14	6.59	94.21	41.58
Ao15	151 (70.9 %)	62 (29.1 %)	<0.001	70.68	22.64	58.52	33.33	54.62
LVH	53 (62.4 %)	32 (37.6 %)	0.642	87.29	29.93	33.33	85.44	43.39
HT								
DAo C	6 (40.0 %)	9 (60.0 %)	0.049	96.03	32.40	33.33	95.86	35.08
Ao15	67 (66.3 %)	34 (33.7 %)	0.443	68.40	21.20	33.33	53.79	50.87
LVH	31 (63.3 %)	18 (36.7 %)	0.957	82.39	28.22	33.33	78.62	42.10
NTH								
DAo C	18 (78.3 %)	5 (21.7 %)	0.042	72.73	51.35	8.22	96.87	45.50
Ao15	84 (75.0 %)	28 (25.0 %)	<0.001	72.28	23.56	33.33	61.64	56.87
LVH	22 (61.1 %)	14 (38.9 %)	0.685	90.87	31.02	33.33	89.95	44.17

GP: general population, HT: Hypertension, NHT: non-hypertensive, DAo C: Dilated aortic root based on echocardiographic consensus, LVH: Left ventricular hypertrophy, Sen: sensitivity (%), Esp: specificity (%), PPV: positive predictive value (%), NPV: negative predictive value (%), ACC: accuracy (%).

Table 3. Sokolow-Lyon-Rappaport index, ventricular hypertrophy, and aortic root enlargement

	SOKOLOW-LYON-RAPPAPORT INDEX N=27							
	Present	Absent	P	Sen	Esp	PPV	NPV	ACC
GP								
DAo C*	4 (10.5 %)	34 (89.5 %)	0.081	10.53	95.95	14.81	85.19	90.59
Ao15	9 (4.2 %)	204 (95.8 %)	0.840	4.23	95.42	33.33	66.67	63.37
LVH	3 (2.9 %)	100 (97.1 %)	0.600	4.71	95.59	14.81	85.19	82.84
HT								
DAo C*	1 (6.7 %)	14 (93.3 %)	0.291	6.67	98.12	20.00	80.00	92.11
Ao15*	2 (2.0 %)	99 (98.0 %)	1.000	1.98	97.64	40.00	60.00	55.26
LVH	0 (0.0 %)	58 (100 %)	0.587	0.00	97.21	0.00	100.00	76.32
NTH								
DAo C	3 (13.0 %)	20 (87.0 %)	0.142	13.04	94.65	13.64	86.36	89.68
Ao15	7 (6.3 %)	105 (93.7 %)	0.817	6.25	94.36	31.82	68.18	68.25
LVH	3 (6.7 %)	42 (93.3 %)	0.736	11.11	94.74	18.18	81.82	86.77

GP: general population, HT: Hypertension, NHT: non-hypertensive, *: Fisher correction,
DAo C: Dilated aortic root based on echocardiographic consensus, LVH: Left ventricular hypertrophy, Sen: sensitivity (%), Esp: specificity (%), PPV: positive predictive value (%), NPV: negative predictive value (%), ACC: accuracy (%).

Table 4. Cornell index, ventricular hypertrophy, and aortic root enlargement

	CORNELL INDEX N=29							
	Present	Absent	P	Sen	Esp	PPV	NPV	ACC
GP								
DAo C*	3 (7.9 %)	35 (92.1 %)	0.417	7.89	95.42	10.34	93.93	89.93
Ao15	17 (8.0 %)	196 (92.0 %)	0.007	7.98	96.95	58.62	41.38	65.68
LVH	12 (11.7 %)	91 (88.3 %)	<0.001	11.65	96.62	41.38	58.62	82.18
HT								
DAo C*	2 (13.3 %)	13 (86.7 %)	0.336	13.33	92.42	11.11	88.89	87.28
Ao15	11 (10.9 %)	90 (89.1 %)	0.135	10.89	94.49	38.89	61.11	57.46
LVH	9 (15.5 %)	49 (84.5 %)	0.013	15.52	94.71	50.00	25.44	74.56
NTH								
DAo C*	1 (3.4 %)	22 (96.6 %)	0.503	4.34	97.18	9.09	94.00	91.53
Ao15*	6 (5.4 %)	106 (94.6 %)	0.091	5.36	98.12	54.55	45.45	70.63
LVH*	3 (6.7 %)	42 (93.3 %)	0.131	6.67	97.60	27.27	26.49	86.77

GP: general population, HT: Hypertension, NHT: non-hypertensive, DAo C: Dilated aortic root based on echocardiographic consensus, LVH: Left ventricular hypertrophy, *: Fisher correction, Sen: sensitivity (%), Esp: specificity (%), PPV: positive predictive value (%), NPV: negative predictive value (%), ACC: accuracy (%).

Sokolow index did not present a relationship between DAo by guidelines or using the CT-derived formula. Regarding LVH the index exhibited only a statistical tendency for a relationship, table 3. Even while, possessing the Cornell index was linked to a higher probability of having an aortic diameter proportion-difference of more than 15 % (OR: 2.754, CI 95%: 1.289-5.881, p=0.007), only 32 out of 606 participants had it, as opposed to the 151 patients who were identified in the new index. Despite finding a high-test specificity (96.79 %), we also discovered a low sensitivity (8.40 %).

Simple linear regression for BSA and Ao diameter showed an R=0.481 for the general population and groups: (HT: R=4.99, NHT: R=0.47). Figure 1 shows a graphic representation of the aortic root diameter and the ECG index in function of BSA for the general population and groups, with a better relationship for the aortic diameter than for the ECG index. In multiple linear analysis, between root aortic diameter and the independent variables; sex, BSA, and the EKG novel index, we discovered a moderate correlation (R=0.573) in the general population (Table 5). The model used brought us 32.9 % of the variables explaining the model and a Durbin-Watson coefficient of 2.04, thereby granting the independence of the observations with great significance (p<0.001). No multicollinearity was found between the independent variables studied. Pearson's correlation was minimal (R=0.076) when sex and BSA were excluded. Comparable outcomes between groups were observed (HT R=0.061, NHT R=0.150).

Finally, three equations were derived to estimate the aortic diameter using the independent variables.

GP- Ao: 22.55 + (-0.056*ECG index score) + (2.779*male) + (4.605*BSA)

HT-Ao: 23.09 + (0.022*ECG index score) + (3.413*male) + (3.561*BSA)

NHT-Ao: 22.79 + (-0.095*ECG index score) + (2.612*male) + (4.832*BSA)

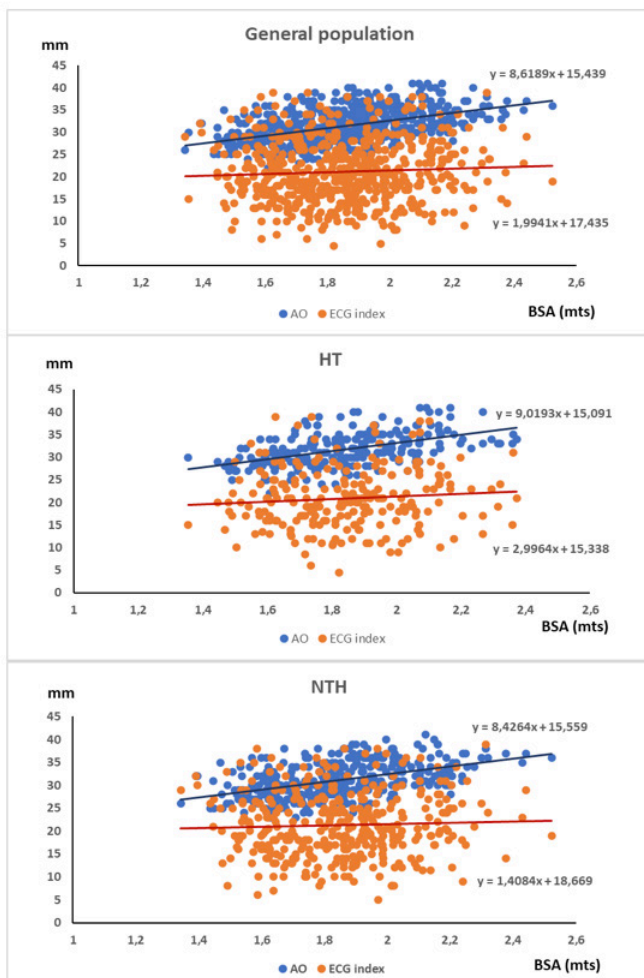

Figure 1. Aortic diameter and ECG index behavior regarding BSA. GP: general population, HT: Hypertension, NHT: non-hypertensive, AO: aortic diameter.

Table 5. Multiple linear regression analysis for aortic diameter and sex, BSA and the EKG index in general, HT and NHT populations

	R R^2	**Unstandardized Coefficients**		**Standardized Coefficients**			**Collinearity Statistics**	
		B	Std. error	Beta	t	Sig.	Tolerance	VIF
	R= 0.573 R^2=0.329							
1	(Constant)	22.595	1,351		16.720	<0.001		
	ECG index score	-0.056	0.018	-0.102	-3.047	0.002	0.996	1.004
	Sex (male)	2.779	0.316	0.373	8.792	<0.001	0.619	1.616
	BSA	4.605	0.761	0.257	6.049	<0.001	0.617	1.621
	R= 0.612 R^2=0.375							
2	(Constant)	23.092	2.192		10.535	<0.001		
	ECG index score	0.022	0.030	0.039	0.731	0.465	0.987	1.014
	Sex (male)	3.413	0.509	0.464	6.705	<0.001	0.583	1.715
	BSA	3.561	1.255	0.197	2.837	0.005	0.578	1.730
	R= 0.576 R^2=0.332							
3	(Constant)	22.788	1.684		13.535	<0.001		
	ECG index score	-0.095	0.023	-0.174	-4.117	<0.001	0.998	1.002
	Sex (male)	2.612	0.398	0.348	6.568	<0.001	0.636	1.572
	BSA	4.832	0.941	0.272	5.134	<0.001	0.636	1.573

Models: 1: General population, 2: Hypertensives, 3: Non-hypertensives, BSA: Body Surface Area, R: multiple correlation coefficient, R^2: coefficient of determination, B: unstandardized coefficient, Std. error: standard error, Beta: standardized coefficient, t: test statist, Sig: significance, VIF: variance inflation factor.

DISCUSSION

LVH detected by electrocardiogram index has been focused on the best estimation of left ventricular mass. Nonetheless, the different initial studies were limited and showed a modest correlation, especially in mild hypertension (22), already suggesting for inclusion of non-electrocardiographic variables. The authors arrived with some questions for the echocardiogram as a validity standard and suggested including other variables besides BSA and sex (23). In this direction, there are some remarks for ethnic's difference finding threshold for LVH, as described in the LIFE Study (24), possibly explained by chest thickness diameter variation among African Americans and whites. In our study, we just applied some of the reported variables evaluating DAo, with exception of ethnicity mainly because our population is eminently mixed. This is today's complex and non-linear behavior relation between genetic traits and phenotype for clinical studies when the self-reported ethnic classification is used (25).

Although we failed to incorporate the ethnic variable, we tried to compensate by studying a formula based on the most common harmony in nature, the PHI number (26,27). In this sense, it was pleasant to observe the proportion in the population for ventricular diastolic/systolic ratio. Additionally, the chest variability evidenced may explain why previous studies have found a stronger correlation between LVH in men when using voltage criteria involving the precordial lead (28).

However, Cornell index comparisons showed that a mix of horizontal and precordial leads with different sex cut off is also suitable, at least in this population for HT patients. Otherwise, the novel ECG index showed more balance between sensitivity and specificity than the Sokolow-Lyon-Rappaport or Cornell index, which were highly specific but poor sensitive. Worth mention the Cornell index was the best in accuracy for LVH in concordance with literature (29) and even was useful in this study when analyzing DAo based on CT.

Regarding aorta, we initially found that the index was uncapable to detect DAo by guide-lines, nonetheless, when divided by group the result was opposite and significant, with fewer patients detected in the HT group. In this matter, the index score associated with DAo in NTH could explain the high negative predictive value of the test. Physiologically these changes can be because they were patients who routinely exercise and somehow might reflets a normal adaptation in the aortic diameter (different observed in hypertension) to regular exercise training as some authors point out that can occur (30). In concordance, we might hypothesize that the index counts if the sum is less than 23 mm, and in hypertensive patients is frequent to observe voltage augmentation.

In another scenario, it is common to see studies that use demographic data as arguments for further normalcy research. Some of them are tailored to populations' anthropometric idiosyncrasies. On the other hand, the studies performed are notably based on the body mass index (BMI). Unfortunately, some authors have shown a poor correlation between the index and the vessel diameter (31). Initial work that showed this relationship was done using BMI ranges and z-scores for cardiac anatomy and further surgery replacement (32), being confirmed by recent studies in large numbers of samples (33). For instance, echocardiographic studies with children and adolescents correlate the aortic root with age, height, and weight (34) with height being the highest correlation obtained. For those limitations, we believed that BSA is superior to BMI determining cardiac chambers.

Even so, while sex and BSA were integrated to improve the linear regression, the index alone exhibited a poor correlation with aortic diameter in the current study. Notwithstanding, based on the golden number, the index could distinguish slight variations in corporal aortic proportions based on CT measures.

With recent breakthroughs for cardiothoracic ratio in tomographic studies (35), the scientific community has largely overlooked the utility of CT values. Afterward, we provided an innovative mathematic equation to favor this anthropometric neglected measure.

As a cross-sectional study, we did face several limitations. There was a lack of data regarding the length of time hypertensive patients' blood pressure was controlled. Likewise, diastolic blood pressure is a proven DAo predictor (36), but we missed to take such values into account when planning our investigation.

Therefore, to better diagnose hypertension organ injury, we might modify actual risk charts and gain a more preventive and accurate medicine, perhaps gold-number-oriented, as exemplified in some medical fields (37). In the same way, a single or ideal value would allow restricting the ranges of normality established in the literature by the cardiology consensus. Today normality is dominated by the Quetelet formula, originally oriented to fit the weight to height proportion in normal men (38). Not to mention, the formula was used to calculate drug distribution volumes but not anatomical concordance estimations. Moreover, the formula frequently classifies obesity incorrectly (39). Consequently, the BMI index has been challenged by adding other anthropometric indexes for risk assessment (body shape index and hip index) (40), outperforming any individual predictors in the Third National Health and Nutrition Examination Survey (NHANES III) data. Those indexes were independent of BMI and could explain the results. On the other hand, if more research takes into account changes in electrocardiographic lead voltages as predictive values in disease outcomes, and not just static values in essence can reflect fulfillments in cohort studies using this new index.

CONCLUSIONS

This new index showed relevant advantages in separating patients with a compromised Ao/VE CT-derived formula and in DAo by guidelines. Universal values determination of aortic diameters and not only in regional populations could allow improvements indicating valve replacement in follow-up aimed for future surgical trials. In this sense, the connection between the golden ratio and ideal health or measures arrives as no surprise.

Ethical disclosure

The authors declare that no experiments were performed on humans for this research.

Confidentiality of data

The authors declare that no patient data appear in this article.

Conflict of interests

There are no conflicts of interest to disclose.

Funding

This study was partially funded by the local institutional health group.

REFERENCES

1. Cuspidi C, Meani S, Fusi V, Valerio C, Sala C, Zanchetti A. Prevalence and correlates of aortic root dilatation in patients with essential hypertension: relationship with cardiac and extracardiac target organ damage. J Hypertens. 2006;24(3):573-580.
2. Masugata H, Senda S, Murao K, Okuyama H, Inukai M, Hosomi N, et al. Aortic root dilatation as a marker of subclinical left ventricular diastolic dysfunction in patients with cardiovascular risk factors. J Int Med Res. 2011;39(1):64-70.
3. Verdecchia P, Porcellati C, Reboldi G, Gattobigio R, Borgioni C, Pearson TA, et al. Left ventricular hypertrophy as an independent predictor of acute cerebrovascular events in essential hypertension. Circulation. 2001;104(17):2039-2044.
4. Verma A, Meris A, Skali H, Ghali JK, Arnold JM, Bourgoun M, et al. Prognostic implications of left ventricular mass and geometry following myocardial infarction: The VALIANT (VALsartan in Acute myocardial iNfarcTion) Echocardiographic Study. JACC Cardiovasc Imaging. 2008;1(5):582-591.
5. Shi HT, Wang XJ, Li J, Song GF, Huang ZY, Guo XY, et al. Association of left ventricular hypertrophy with a faster rate of renal function decline in elderly patients with non-end-stage renal disease. J Am Heart Assoc. 2015;4(11):e002213.
6. Laukkanen JA, Khan H, Kurl S, Willeit P, Karppi J, Ronkainen K, et al. Left ventricular mass and the risk of sudden cardiac death: A population-based study. J Am Heart Assoc. 2014;3(6):e001285..
7. Isselbacher EM. Thoracic and abdominal aortic aneurysms. Circulation. 2005;111(6):816-828.
8. Henry WL, Gardin JM, Ware JH. Echocardiographic measurements in normal subjects from infancy to old age. Circulation. 1980;62(5):1054-1061.
9. Teixido-Tura G, Almeida AL, Choi EY, Gjesdal O, Jacobs DR Jr, Dietz HC, et al. Determinants of aortic root dilatation and reference values among young adults over a 20-year period: Coronary artery risk development in young adults study. Hypertension. 2015;66(1):23-29.
10. Howard DP, Banerjee A, Fairhead JF, Perkins J, Silver LE, Rothwell PM, et al. Population-based study of incidence and outcome of acute aortic dissection and premorbid risk factor control: 10-year results from the Oxford vascular study. Circulation. 2013;127(20):2031-2037.
11. Cuspidi C, Facchetti R, Bombelli M, Sala C, Tadic M, Grassi G, et al. Does QRS voltage correction by body mass index improve the accuracy of electrocardiography in detecting left ventricular hypertrophy and predicting cardiovascular events in a general population? J Clin Hypertens (Greenwich). 2016;18(5):415-421.
12. Gasperin CA, Germiniani H, Facin CR, Souza AM, Cunha CL. An analysis of electrocardiographic criteria for determining left ventricular hypertrophy. Arq Bras Cardiol. 2002;78(1):59-82.
13. Singla V, Jindal A, Pargaonkar V, Soofi M, Wheeler M, Froelicher V. Examining QRS amplitude criteria for electrocardiographic left ventricular hypertrophy in recommendations for screening criteria in athletes. J Electrocardiol. 2015;48(3):368-372.
14. Hedman K, Moneghetti KJ, Hsu D, Christle JW, Patti A, Ashley E, et al. Limitations of electrocardiography for detecting left ventricular hypertrophy or concentric remodeling in Athletes. Am J Med. 2020;133(1):123-132.e8.
15. Bula K, Ćmiel A, Sejud M, Sobczyk K, Ryszkiewicz S, Szydło K, et al. Electrocardiographic criteria for left ventricular hypertrophy in aortic valve stenosis: Correlation with echocardiographic parameters. Ann Noninvasive Electrocardiol. 2019;24(5):e12645.
16. Lang RM, Biering M, Devereux RB, Flachskampf FA, Foster E, Pellikka PA, et al. Recommendations for chamber quantification: a report from the American Society of Echocardiography's guidelines and standards committee and the chamber quantification writing group, developed in conjunction with the European Association of Echocardiography, a branch of the European Society of Cardiology. J Am Soc Echocardiogr. 2005;18(12):1440-1463.
17. Macruz R. Matemática da arquitectura humana V=K*ET. Brasil: Editora Roca; 2010.
18. Pinto VF. Non-inferiority trials: concepts and issues. J Vasc Bras. 2010;9(3):145-151.
19. Angelo LC, Vieira ML, Rodrigues SL, Morelato RL, Pereira AC, Mill JG, et al. Echocardiographic reference values in a sample of asymptomatic adult Brazilian population. Arq Bras Cardiol.

2007;89(3):168-173, 184-190.

20. Drexler M, Erbel R, Müller U, Wittlich N, Mohr-Kahaly S, Meyer J. Measurement of intracardiac dimensions and structures in normal young adult subjects by transesophageal echocardiography. Am J Cardiol. 1990;65(22):1491-1496.
21. Devereux RB, de Simone G, Arnett DK, Best LG, Boerwinkle E, Howard BV, et al. Normal limits in relation to age, body size and gender of two-dimensional echocardiographic aortic root dimensions in persons 15 years of age. Am J Cardiol. 2012;110(8):1189-1194.
22. Crow RS, Prineas RJ, Rautaharju P, Hannan P, Liebson PR. Relation between electrocardiography and echocardiography for left ventricular mass in mild systemic hypertension (results from Treatment of Mild Hypertension Study). Am J Cardiol. 1995;75(17):1233-1238.
23. Crow, RS, Hannan P, Grandits G, Liebson P. Is the echocardiogram an appropriate ECG validity standard for the detection and change in left ventricular size? J Electrocardiol. 1996; 29:248-255.
24. Okin PM, Wright JT, Nieminen MS, Jern S, Taylor AL, Phillips R, et al. Ethnic differences in electrocardiographic criteria for left ventricular hypertrophy: The LIFE study. Losartan intervention for endpoint. Am J Hypertens. 2002;15(8):663-671.
25. Paschetta C, de Azevedo S, Ramallo V, Cintas C, Pérez O, Navarro P, et al. The impact of socioeconomic and phenotypic traits on self-perception of ethnicity in Latin America. Sci Rep. 2021;11(1):12617.
26. Yalta K, Ozturk S, Yetkin E. Golden Ratio and the heart: A review of divine aesthetics. Internat J Cardiol. 2016;1(214):107-112.
27. Ilić I, Stefanović M, Sadiković D. Mathematical determination in nature: The golden ratio. Acta Med Medianae. 2018;57(3):124-129.
28. Colossimo AP, Costa Fde A, Riera AR, Bombig MT, Lima VC, Fonseca FA, et al. Electrocardiogram sensitivity in left ventricular hypertrophy according to gender and cardiac mass. Arq Bras Cardiol. 2011;97(3):225-231.
29. Peguero JG, Lo Presti S, Pérez J, Issa O, Brenes JC, Tolentino AJ. Electrocardiographic criteria for the diagnosis of left ventricular hypertrophy. Am Coll Cardiol. 2017;69(13):1694-1703.
30. Monda E, Verrillo F, Rubino M, Palmiero G, Fusco A, Cirillo A, et al. Thoracic aortic dilation: Implications for physical activity and sport participation. Diagnostics (Basel). 2022;12(6):1392.
31. Westaby S, Karp RB, Blackstone EH, Bishop SP. Adult human valve dimensions and their surgical significance. Am J Cardiol. 1984;53(4):552-556.
32. Kirklin JW, Barratt-Boyes BG. Anatomy, dimensions, and terminology. In: Kirklin JW, Barratt-Boyes BG, editors. Cardiac surgery. 2nd edition. New York: Churchill Livingstone; 1993.p.3-60.
33. Capps SB, Elkins RC, Fronk DM. Body surface area as a predictor of aortic and pulmonary valve diameter. J Thorac Cardiovasc Surg. 2000;119(5):975-982.
34. Sheil ML, Jenkins O, Sholler GF. Echocardiographic assessment of aortic root dimensions in normal children based on measurement of a new ratio of aortic size independent of growth. Am J Cardiol. 1995;75(10):711-715.
35. Tomita H, Yamashiro T, Matsuoka S, Matsushita S, Kurihara Y, Nakajima Y. Changes in cross-sectional area and transverse diameter of the heart on inspiratory and expiratory chest CT: Correlation with changes in lung size and influence on cardiothoracic ratio measurement. PLoS One. 2015;10(7):e0131902.
36. Canciello G, Mancusi C, Izzo R, Morisco C, Strisciuglio T, Barbato E, et al. Determinants of aortic root dilatation over time in patients with essential hypertension: The Campania Salute Network. Eur J Prev Cardiol. 2020;12:2047487320931630.
37. Lanz-Luces JR. Phi, el áureo en la medicina. España: Editorial Académica Española; 2018.
38. Eknoyan G. Adolphe Quetelet (1796-1874) - the average man and indices of obesity. Nephrol Dial Transplant. 2008;23(1):47-51.
39. Freigang R, Geier AK, Schmid GL, Frese T, Klement A, Unverzagt S. Misclassification of self-reported body mass index categories. Dtsch Arztebl Int. 2020;117(15):253-260.
40. Krakauer NY, Krakauer JC. An anthropometric risk index based on combining height, weight, waist, and hip measurements. J Obes. 2016;2016:8094275.