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ORIGINAL RESEARCH

The Diagnostic Value of the Deepest S Wave in 12-Lead Electrocardiogram to Elderly Patients with Essential Hypertension and Left Ventricular Hypertrophy

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Objective: This study aims to explore the diagnostic value of the deepest S wave (S_D) in elderly patients with essential hypertension and left ventricular hypertrophy (LVH).

Methods: A retrospective study was conducted in elderly patients with essential hypertension from October 2020 to December 2021. The 12-lead electrocardiogram (ECG) examination was carried out at the time of admission. Echocardiography was performed to estimate left ventricular mass (LVM) and the left ventricular muscle mass index (LVMI) was adjusted by the body surface area (BSA). The Receiver Operating Characteristic (ROC) curve for diagnosing hypertension with LVH was drawn, the cut-off value was determined according to the Youden index, and the area under the curve (AUC) was calculated. The diagnostic values of S_D, S_D +S_{v4}, r_{avl}+S_{v3}, and S_{v1}+R_{v5} were compared.

Results: The results of S_D, S_D+S_{v4}, R_{avL}+S_{v3}, and S_{v1}+R_{v5} in the Study group were 2.03 (1.56–2.57) mV, 3.09 (2.38–3.98) mV, 2.19 (1.46–2.78) mV, and 3.38 (2.67–4.19) mV respectively, which were all higher than those in the Control group [0.93 (0.68–1.23) mV, 1.37 (1.32–2.18) mV, 1.03 (0.68–1.46) mV, and 2.28 (1.67–2.67) mV], $P<0.001$. Compared with the ROC curved by S_D+S_{v4}, R_{avL}+S_{v3}, and S_{v1}+R_{v5}, the AUC of the ROC curved by S_D was [0.887, 95% CI (0.837–0.927)], and the cut-off value was 1.298 with the Sensitivity = 86.03 and Specificity = 86.59 in diagnosing essential hypertension with LVH. In female patients, the AUC of the ROC curved by S_D was [0.891, 95% CI (0.841–0.934)], and the cut-off value was 1.304 with the Sensitivity of 89.32% and Specificity of 88.67%, which were all higher than those in male patients [AUC = 0.887, 95% CI (0.828–0.943); cut-off value = 1.288; Sensitivity = 82.12%, and Specificity = 84.22%].

Conclusion: ECG can effectively diagnose elderly patients with essential hypertension and LVH and the diagnostic value of S_D and S_D+S_{v4} are higher than the current Cornell criteria and Sokolow–Lyon criteria.

Keywords: essential hypertension, left ventricular hypertrophy, elderly patients, deepest S wave, electrocardiogram criteria

Introduction

With continuous changes in people's living habits and dietary structure, about one-third of adults suffer from hypertension, and about 750,000 people die each year due to cardiovascular and cerebrovascular accidents caused by hypertension.[1] China has become an aging society and hypertension is one of the most common chronic diseases in the elderly.[2,3] Essential hypertension is a cardiovascular syndrome with elevated systemic arterial pressure as the main clinical manifestation.[4] Poor long-term control of blood pressure results in a corresponding change in the structure of the heart, that is, left ventricular hypertrophy (LVH). LVH can increase the risk of cardiovascular diseases such as arrhythmia, myocardial ischemia, heart failure, and sudden cardiac death, posing a serious threat to the life and health

of patients.[5] In recent years, related reports have pointed out that early diagnosis and treatment can prevent and reverse LVH, thereby improving the prognosis of patients.[6] Therefore, early, timely and accurate diagnosis of essential hypertension with LVH has become a hotspot of clinical research.

The 12-lead electrocardiogram (ECG) has the advantages of easy operation, good repeatability, non-invasiveness, and economy, and has been widely used in clinical practice.[7] At present, the Cornell criteria and Sokolow–Lyon criteria are often used clinically for ECG diagnosis of LVH, but the sensitivity of these two methods is only 20–50%.[8] Peguero et al has proposed a new diagnostic standard: S_D+S_{v4} standard, which is the sum of the amplitude of the deepest S wave in any lead (S_D) and the amplitude of the S wave in lead V4 (S_{v4}); $S_D+S_{v4} \geq 2.8$ mV in male patients and $S_D+S_{v4} \geq 2.3$ mV in female patients are the diagnosed criteria for LVH.[8] The sensitivity of S_D+S_{v4} criteria for diagnosing LVH was higher than 62%, which was significantly higher than other traditional diagnostic criteria.[8] However, the S_D+S_{v4} standard was proposed based on a small sample population, which has not been validated in the domestic population.

Based on the above background, this study aimed to explore the diagnostic value of the deepest S wave (S_D) in elderly patients with essential hypertension and LVH, to provide clinical evidence.

Methods and Material

Population

A retrospective study was conducted in elderly patients with essential hypertension who were admitted to our hospital from October 2020 to December 2021. According to the inclusion and exclusion criteria, there were 106 elderly patients with essential hypertension and left ventricular hypertrophy, and 90 patients were selected to form the Study group; by propensity matching of the age and gender, with a ratio of 0.9:1, 100 essential hypertensive patients were randomly selected from the remaining patients to form a Control group.

This study protocol complies with the relevant requirements of the Declaration of Helsinki of the World Medical Association and ethics approval was waived by our hospital because the review of patients' data is anonymous. Patient enrollment flow chart is shown in Figure 1.

Inclusion and Exclusion Criteria

Inclusion criteria: (1) Age > 60 years old. A definite diagnosis of essential hypertension;[9] (2) A definite diagnosis of left ventricular hypertrophy;[10] (3) A normal mental state; (4) Agreed to participate in this study and signed written informed consent.

Exclusion criteria: (1) Combination of hematological diseases such as leukemia and anemia; (2) Combination of immune diseases such as autoimmune thyroiditis, Hashimoto's thyroiditis, and immune thrombocytopenic purpura; (3) Combination liver and kidney diseases such as functional acute renal failure, decompensated cirrhosis; (4) Existence of cardiovascular system and pulmonary infection such as lobar pneumonia, lobular pneumonia, and infectious myocarditis; (5) Existence of pulmonary diseases such as respiratory infections, bronchial diseases, and lung cancer; (6) Combination of cardiomyopathy, heart valve disease, and severe arrhythmia; (7) A definite diagnosis of secondary hypertension; (8) Combined with complete left or right bundle branch block; (9) Implanted pacemaker and the presence of paced rhythm.

ECG Examination and Data Measurement

The 12-lead ECG examination was carried out at the time of admission. Foton FX7402 electrocardiographic comprehensive automatic analyzer was used, the speed was set to 25 mm/s, and the calibration was 10 mm/mV. Before the examination, the patients were made comfortable for 10 minutes in a quiet environment. Electrodes were placed in conventional positions, with the ECG baseline being stable, free of interference, and the graph was clear. 4–6 cardiac cycles were recorded in every lead, and 3 consecutive ECG cycles with a stable baseline were selected.

The PR segment was set as the baseline, individual leads were analyzed by measuring the highest R and deepest S waves in all precordial and limb leads, and only the largest compound voltage was selected in the presence of voltage differences within the same lead. The deepest S wave in the ECG was defined as S_D, and the sum of the amplitude of the deepest S wave (S_D) in all leads and the amplitude of the S wave in lead V4 (S_{v4}) is defined as S_D+S_{v4}. The Cornell standard is the amplitude of the R wave in lead
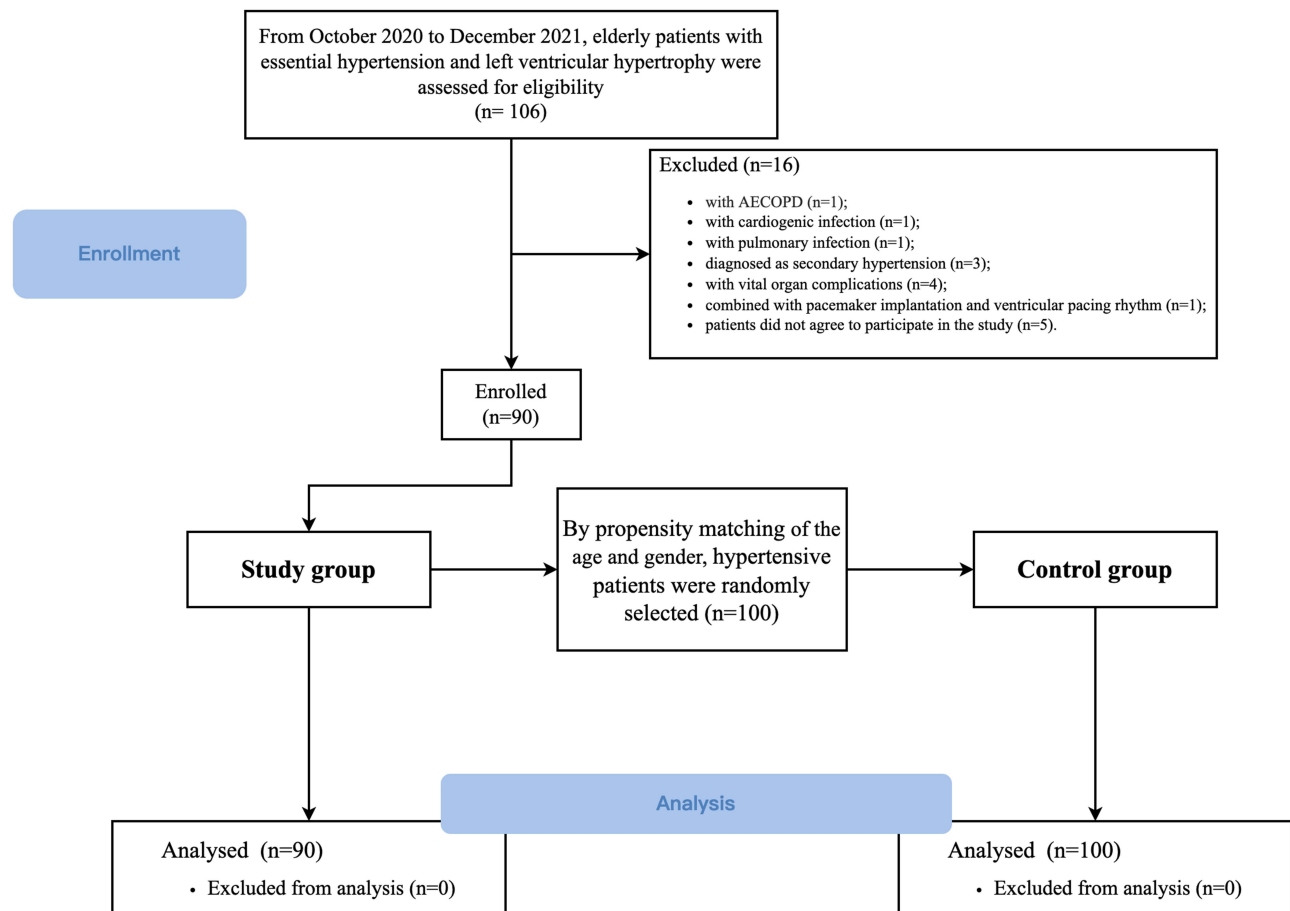
Figure 1 Patient enrollment flow chart.
Abbreviation: AECOPD, acute exacerbation of chronic obstructive pulmonary disease.

avL plus the amplitude of the S wave in lead V3 ($R_{avL}+S_{v3}$); the Sokolow–Lyon standard is the amplitude of the S wave in lead V1 plus the amplitude of the higher R wave in lead V5 ($S_{v1}+R_{v5}$).

The above data were all obtained and analyzed by independent physicians who had more than 8-year experience and did not know the grouping of patients.

Ultrasonography and Measurement of Left Ventricular Mass

Echocardiography was performed on the same day as the ECG was carried out. Transthoracic echocardiography (TTE) was used as the reference method to estimate left ventricular mass (LVM). A Philips EPIQ 7C echocardiograph with an X5-1 probe in a frequency of 50 MHz was used to perform the TTE. Patients were instructed to breathe calmly and in the left lateral position, and the limb lead electrocardiogram was recorded synchronously. The interventricular thickness (IV thickness), left ventricular end-diastolic diameter (LVed), left ventricular posterior wall thickness (LV posterior wall thickness), and ejection fraction were recorded in the parasternal long-axis view. LVM was calculated according to the American Society of Echocardiography (ASE) recommendation and the LVH was definitely diagnosed:[10] LVM (g) = $0.8\times1.04\times[$(IV thickness+LVed+LV posterior wall thickness$)^3-$ LVed$^3]+0.6$. Left ventricular muscle mass index (LVMI) was the result of the LVM adjusted by the body surface area (BSA). The diagnostic criteria for LVH in female patients was LVMI>95 g/m^2 and in male patients was LVMI>115 g/m^2.

The above data were all obtained and recorded by independent physicians who had more than 8-year experience and did not know the grouping of patients.

Observation Index

The clinical data (gender, age, body surface area, heart rate and blood pressure at admission), the comorbid diseases (peripheral vascular disease, diabetes, carotid plaque), results of ultrasound examinations (ejection fraction, LVMI, left ventricular posterior wall thickness, interventricular thickness), and the drug usage (calcium channel inhibitors, ACE inhibitors/ARBs, beta receptor inhibitors) of the two groups were collected.

The patients' ECG parameters were taken as the main research objects, and the results of S_D, S_D+S_{v4}, $r_{avl}+S_{v3}$, and $S_{v1}+R_{v5}$ were obtained from each patient.

Statistics

SPSS 22.0 software was used to analyze the data. Kolmogorov–Smirnov method was used for normality test. Normally distributed measurement data were expressed as mean ± standard deviation (SD), and Student's t-test was used for comparisons, while non-normally distributed measurement data were expressed as median (interquartile range), and the comparisons were examined by Mann–Whitney test (non-parametric distribution). The categorical data were expressed as n (%), and the differences between the two groups were examined by chi-square analysis or Fisher's exact test. $P<0.05$ was considered statistically significant.

According to the results of S_D, S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ in the two groups, the Receiver Operating Characteristic (ROC) curve for diagnosing hypertension with LVH was drawn, and the cutoff value was determined according to the Youden index, and the area under the curve (AUC) was calculated. Equivalence tests were compared by Z-scores calculated by Med Calc software. $P<0.05$ was considered a statistically significant difference.

Result

From October 2020 to December 2021, elderly patients with essential hypertension who were admitted to our hospital were retrospectively included in this study. According to the inclusion and exclusion criteria, there were 106 elderly patients with essential hypertension and LVH, and 90 patients were selected to form the Study group; a total of 16 patients were excluded for the following reasons: 1 patient combined with acute exacerbation of chronic obstructive pulmonary disease (AECOPD), 1 patient combined with cardiogenic infection, 1 patient combined with pulmonary infection, 3 patients were diagnosed as secondary hypertension, 4 patients combined with vital organ complications, 1 patient combined with pacemaker implantation and ventricular pacing rhythm, and 5 patients did not agree to participate in this study. Then based on the age and gender of the patients, 100 hypertensive patients were randomly selected to form the Control group by propensity matching. In the Study group, there were 64 males and 26 females, with an average age of 68.97±10.43 years. In the Control group: there were 78 males and 22 females, with an average age of 68.91±10.34 years (see Figure 1).

Demographic Comparisons

There were no significant differences in two groups among gender, age, comorbidities (peripheral vascular disease, diabetes, carotid atherosclerotic plaque), heart rate at the admission, ejection fraction assessed by the ultrasound, and drug usage (calcium channel inhibitors, angiotensin converting enzyme (ACE) inhibitors/angiotensin receptor blockers (ARBs), β-receptor inhibitors), $P>0.05$. The body surface area of the Study group was 1.75±0.23 m^2, which was higher than that of the Control group (1.65±0.24 m^2) with statistically significant differences, $P = 0.004$. The systolic blood pressure and diastolic blood pressure of the Study group at admission were 162.28 (154.93–171.04) mmHg and 99.09 (92.00–107.04) mmHg respectively, which were higher than those of the Control group [141.34 (132.32–149.73) mmHg vs 95.34 (85.36–101.08) mmHg], $P<0.001$. The Left ventricular posterior wall thickness and the interventricular thickness of the Study group were 13.08 (11.98–13.67) mm and 13.07 (12.78–14.23) mm, respectively, which were significantly higher than those of the Control group [8.81 (8.09–9.49) mm vs 8.78 (8.07–9.53) mm], $P<0.001$. The left ventricular muscle weight index of the Study group was 123.87 (116.31–142.89), which was higher than that of the Control group [64.09 (55.38–80.09)], $P<0.001$ (see Table 1).

Table 1 Demographic Comparisons

Items	Study Group (n = 90)	Control Group (n = 100)	X^2/t	P value
Male/Female	64/26	78/22	1.191	0.275
Age (years)	68.97±10.43	68.91±10.34	0.040	0.968
Body surface area (m^2)	1.75±0.23	1.65±0.24	2.925	0.004*
Comorbidity				
Peripheral vascular disease (%)	5 (5.56)	4 (4.00)	0.254	0.614
Diabetes (%)	10 (11.11)	9 (9.00)	0.235	0.628
Carotid atherosclerotic plaques (%)	6 (6.67)	4 (4.00)	0.421	0.748
Heart rate and blood pressure upon admission				
Heart rate (beats per minute)	70.03 (61.05–84.03)	74.07 (61.16–86.19)	0.917	0.103
Diastolic blood pressure (mmHg)	99.09 (92.0–107.04)	95.34 (85.36–101.08)	−5.087	<0.001*
Systolic blood pressure (mmHg)	162.28 (154.93–171.04)	141.34 (132.32–149.73)	−16.214	<0.001*
Ultrasound results				
Ejection fraction (%)	63.52 (58.82–66.3)	63.91 (59.84–66.82)	1.623	0.103
Left ventricular muscle weight index (g/m^2)	123.87 (116.31–142.89)	64.09 (55.38–80.09)	−26.004	<0.001*
Left ventricular posterior wall thickness (mm)	13.08 (11.98–13.67)	8.81 (8.09–9.49)	−32.122	<0.001*
Interventricular thickness (mm)	13.07 (12.78–14.23)	8.78 (8.07–9.53)	−34.368	<0.001*
Medication usage				
Using calcium channel blockers (%)	28 (31.11)	27 (27.00)	0.389	0.533
Using ACEI inhibitors/ARBs (%)	41 (45.56)	43 (43.00)	0.125	0.723
Using β receptor inhibitors (%)	43 (47.78)	47 (47.00)	0.011	0.915

Note: *Compared with Study group, $P<0.05$.

Comparisons of Measured Values of Electrocardiogram Between the Two Groups

The results of S_D, S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ in the Study group [2.03 (1.56–2.57) mV, 3.09 (2.38–3.98) mV, 2.19 (1.46–2.78) mV, and 3.38 (2.67–4.19) mV respectively] were all higher than those in the Control group [0.93 (0.68–1.23) mV, 1.37 (1.32–2.18) mV, 1.03 (0.68–1.46) mV, and 2.28 (1.67–2.67) mV], $P<0.001$ (see Table 2.)
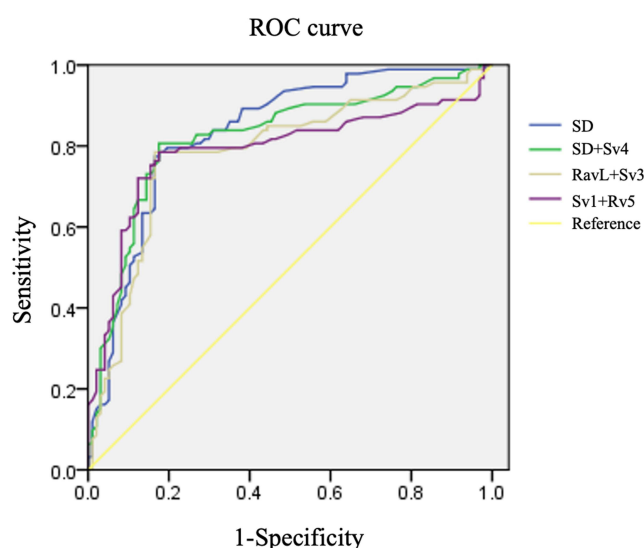
Diagnostic Value of S_D, S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ in Elderly Patients with Essential Hypertension Complicated with Left Ventricular Hypertrophy

Compared with the ROC curved by S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$, the AUC of the ROC curved by S_D was [0.887, 95% CI (0.837–0.927)], and the cut-off value was 1.298 with the Sensitivity = 86.03% and Specificity = 86.59% in diagnosing essential hypertension with LVH. The AUC of the ROC curved by S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ were [0.859, 95% CI (0.811–0.899)], [0.838, 95% CI (0.789–0.893)], and [0.817, 95% CI (0.768–0.869)] respectively; and the Sensitivity and the Specificity of the ROC curved by S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ were (cut-off value = 1.823; 85.36% vs 85.52%), (cut-off value = 1.613; 73.62% vs 83.06%), and (cut-off value = 2.693; 72.83% vs 83.04%) respectively (see Figure 2 and Table 3).

Table 2 Comparisons of Measured Values of Electrocardiogram Between the Two Groups

Items	Study Group (n = 90)	Control Group (n = 100)	X^2/t	P value
S_D (mV)	2.03 (1.56–2.57)	0.93 (0.68–1.23)	−12.048	<0.001*
S_D+S_{v4} (mV)	3.09 (2.38–3.98)	1.37 (1.32–2.18)	−11.042	<0.001*
$R_{avL}+S_{v3}$ (mV)	2.19 (1.46–2.78)	1.03 (0.68–1.46)	−10.825	<0.001*
$S_{v1}+R_{v5}$ (mV)	3.38 (2.67–4.19)	2.28 (1.67–2.67)	−8.936	<0.001*

Note: *Compared with Study group, $P<0.05$.

Figure 2 ROC curve of the diagnostic value of S_D, S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ in elderly patients with essential hypertension and LVH.

Diagnostic Value of S_D, S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ in Elderly Male and Female Patients with Essential Hypertension Complicated with Left Ventricular Hypertrophy

In female patients, the AUC of the ROC curved by S_D was [0.891, 95% CI (0.841–0.934)], and the cut-off value was 1.304 with the Sensitivity = 89.32% and Specificity = 88.67%, which were all higher than those in male patients [AUC = 0.887, 95% CI (0.828–0.943); cut-off value = 1.288; Sensitivity = 82.12%, and Specificity = 84.22%]. The Sensitivity and Specificity of the ROC curved by S_D+S_{v4} in female patients were 88.98 and 89.68 respectively, which were higher than those in male patients, and were higher than those ROC curved by $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ in male (Sensitivity = 81.79%, and Specificity = 83.26% vs Sensitivity = 81.97%, and Specificity = 83.21%) and female patients (Sensitivity = 83.66%, and Specificity = 85.39% vs Sensitivity = 82.92%, and Specificity = 85.0%1). The AUC of the ROC curved by S_D+S_{v4}, $r_{avl}+S_{v3}$, and $S_{v1}+R_{v5}$ in males were [AUC = 0.803, 95% CI (0.794–0.956), AUC = 0.829, 95% CI (1.027–1.683), and AUC = 0.809, 95% CI (0.739–0.869)] and in females were [AUC = 0.791, 95% CI (0.793–0.948), AUC = 0.838, 95% CI (1.009–1.693), and AUC = 0.809, 95% CI (0.757–0.884)] (see Figures 3–4 and Tables 4–5).

Discussion

Hypertension is a chronic disease that requires long-term control. When hypertension develops to a certain level, it will lead to ventricular hypertrophy, and in severe cases, it will further lead to left ventricular failure and even death.[11] Therefore, early diagnosis of elderly hypertensive patients with LVH is helpful for early treatment and may be related to a better prognosis outcome. For its simplicity, low price, convenience, and repeatability, electrocardiography is often used as the preferred examination for screening, diagnosing, and evaluating cardiac diseases. LVH is associated with an increase in the left ventricular weight, and the ECG can detect left ventricular hypertrophy by detecting an increase in
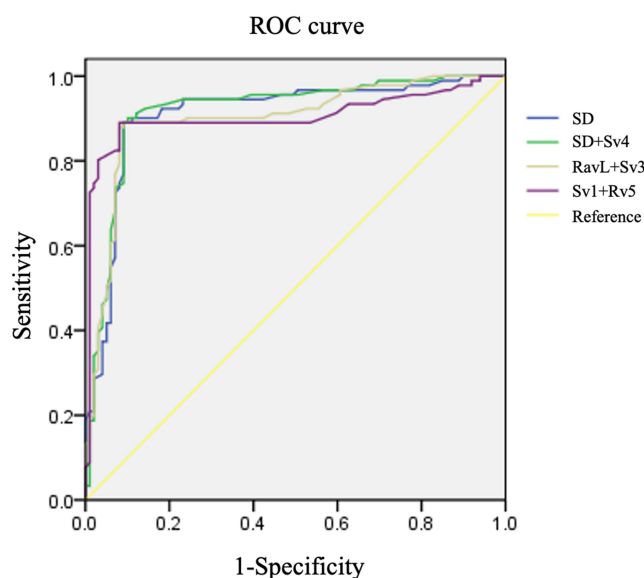
Table 3 Diagnostic Value of SD, SD+Sv4, RavL+Sv3, and Sv1+Rv5 in Elderly Patients with Essential Hypertension Complicated with Left Ventricular Hypertrophy

Items	AUC	SE	95% CI	Cut-off Value	Sensitivity(%)	Specificity(%)
S_D (mV)	0.887	0.017	0.837–0.927	1.298	86.03	86.59
S_D+S_{v4} (mV)	0.859	0.026	0.811–0.899	1.823	85.36	85.52
$R_{avL}+S_{v3}$ (mV)	0.838	0.024	0.789–0.893	1.613	73.62	83.06
$S_{v1}+R_{v5}$ (mV)	0.817	0.029	0.768–0.869	2.693	72.83	83.04
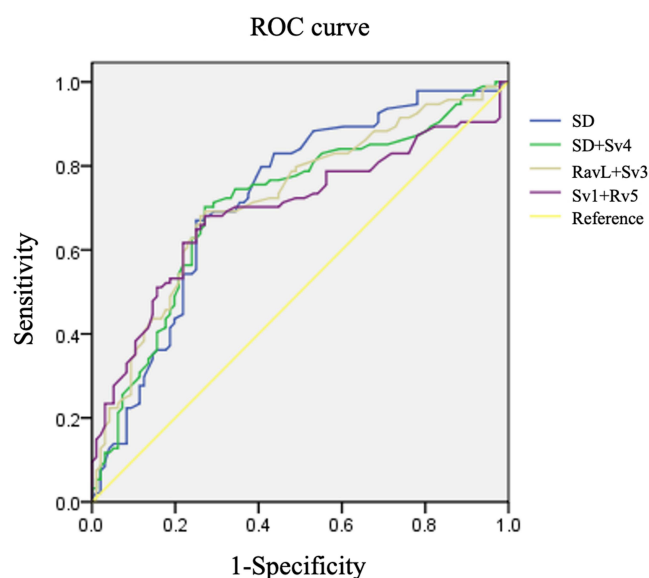
ROC curve

Figure 3 ROC curve of the diagnostic value of S_D, S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ in elderly male patients with essential hypertension and LVH.

ROC curve

Figure 4 ROC curve of the diagnostic value of S_D, S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ in elderly female patients with essential hypertension and LVH.

voltage, which makes the ECG a good basis for assessing changes in left ventricular mass.[12] The 2016 Asian Expert Consensus on the Diagnosis and Treatment of Hypertension and Left Ventricular Hypertrophy clearly pointed out that an electrocardiogram is the first choice for screening and diagnosing hypertension and left ventricular hypertrophy.[13] The results of this study showed that, compared with the Control group, patients in the Study group had statistically significant differences in body surface area, heart rate, diastolic blood pressure, systolic blood pressure, left ventricular muscle weight index, left ventricular posterior wall thickness, and interventricular thickness, suggesting that the elderly patients with essential hypertension and LVH may have the basis of abnormal ECG results.

A study by Durrer et al[14] pointed out that the S wave in the last 50 ms of the QRS wave is generated by the depolarization of the left ventricle cardiomyocytes and the left ventricular free wall, which can better reflect the main depolarization vector of the left ventricle. The location of myocardial hypertrophy varies among individuals and is not limited to the recording range of a certain lead; in addition, the ECG vector generated after depolarization of the

Table 4 Diagnostic Value of S_D, S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ in Elderly Male Patients with Essential Hypertension Complicated with Left Ventricular Hypertrophy

Items	AUC	SE	95% CI	Cut-off Value	Sensitivity(%)	Specificity(%)
S_D (mV)	0.887	0.025	0.828–0.943	1.288	82.12	84.22
S_D+S_{v4} (mV)	0.803	0.027	0.794–0.956	1.852	81.87	83.08
$R_{avL}+S_{v3}$ (mV)	0.829	0.283	1.027–1.683	1.712	81.79	83.26
$S_{v1}+R_{v5}$ (mV)	0.809	0.029	0.739–0.869	1.735	81.97	83.21

Table 5 Diagnostic Value of S_D, S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ in Elderly Female Patients with Essential Hypertension Complicated with Left Ventricular Hypertrophy

Items	AUC	SE	95% CI	Cut-off Value	Sensitivity(%)	Specificity(%)
S_D (mV)	0.891	0.021	0.841–0.934	1.304	89.32	88.67
S_D+S_{v4} (mV)	0.791	0.029	0.793–0.948	1.843	88.98	89.68
$R_{avL}+S_{v3}$ (mV)	0.838	0.289	1.009–1.693	1.709	83.66	85.39
$S_{v1}+R_{v5}$ (mV)	0.809	0.022	0.757–0.884	2.732	82.92	85.01

hypertrophic myocardium is not necessarily parallel to the direction of the lead, so S_D, the amplitude of the deepest S wave, was chosen to fully reflect the change of the left ventricular depolarization vector.[8] The results of this study showed that the voltage values of S_D, S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ in the Study group were higher than those in the Control group, indicating that the elderly patients with essential hypertension and LVH had obvious ECG abnormalities, and S_D, S_D+S_{v4}, $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$ had significantly risen.

Research by Xia[15] et al pointed out that S_D+S_{v4} standard is superior to Cornell standard and Sokolow–Lyon standard in diagnosing LVH; Shao[16] et al also believed that S_D+S_{v4} standard can be more effective than Cornell standard and Sokolow–Lyon standard. The results of this study showed that the AUC value, sensitivity and specificity of the ROC curved by S_D and S_D+S_{v4} were all better than those of the ROC curved by $R_{avL}+S_{v3}$, and $S_{v1}+R_{v5}$, the Cornell standard and the Sokolow–Lyon standard, suggesting that S_D and S_D+S_{v4} could be used to diagnose elderly patients with essential hypertension and LVH. Excluding the differences of study subjects and ethnics, in the first half of ventricular depolarization, the Q wave and R wave ascending branch represent the depolarization of the interventricular septum, conduction system (His bundle, left and right bundle branches, and Purkinje fibers), and endomyocardial fibers. The polarization process, while the descending part of the R wave and the S wave appears in the second half of the depolarization, represents the depolarization of the left ventricular myocardium and epicardial free wall, which can explain that changes in S_D and can reflect mild to moderate left ventricular voltage changes in hypertrophic patients.

Zhang[17] et al studied elderly patients over 65 years old in the community, and the results showed there was no gender difference in LVMI in patients with LVH. Félix-Redondo[18] et al pointed out that heart size, the thickness of the subcutaneous fat layer, hormone levels, and tissue conductivity may affect the diagnostic efficacy in gender. The results of this study showed that in different genders, the ROC curves drawn by S_D and S_D+S_{v4} can be used for the diagnosis of essential hypertension with LVH; compared with male patients, the AUC, sensitivity, and specificity of the ROC curves drawn by S_D and S_D+S_{v4} in female patients were higher, suggesting that S_D and S_D+S_{v4} have a better diagnostic value in female patients for essential hypertension with LVH. Studies by Michel[19] et al pointed out that the adaptation of the heart to pressure overload resulted in the remodeling of the myocardium in an earlier stage for the changes of hormones. Sun Rong[20] and other studies thought estrogen can prevent the deposition of collagen in myocardial cells, and can inhibit angiotensin-induced collagen synthesis. Therefore, it is speculated that the myocardial interstitial remodeling in the elderly male patients with essential hypertension with LVH may be more severe than that in the female patients of the

same age, which leads to the weakening of the cardiac electrical activity of the hypertrophic myocardium on the electrocardiogram, and this, in turn, reduced the diagnostic performance of the ECG.

The research also has the following shortcomings: (1) This study is a single-center, retrospective analysis, and there is a selection bias in the included patients. Therefore, the community population should be further selected for a controlled study in the later stage. (2) There is no cross-validation between the results of cardiac magnetic resonance imaging (MRI) and the results measured by echocardiography.

Conclusion

ECG can effectively diagnose elderly patients with essential hypertension and left ventricular hypertrophy, and the diagnostic value of S_D and S_D+S_{v4} is higher than the current Cornell criteria and Sokolow–Lyon criteria.

Disclosure

The authors report no conflicts of interest in this work.

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