Medical Principles and Practice

Original Paper

Med Princ Pract 2022;31:463–470
DOI: 10.1159/000525433

Received: January 26, 2022
Accepted: June 7, 2022
Published online: June 9, 2022

Association between RS Time in Electrocardiogram and Right Ventricular Functions in Patients with Chronic Obstructive Pulmonary Disease

Ibrahim Yildiz[a] Pinar Ozmen Yildiz[b] Husamettin Sazlidere[c]
Mehmet Sait Gurevin[b] Ibrahim Rencuzogullari[d] Yavuz Karabag[d]

[a]Department of Cardiology, Adana Çukurova State Hosipital, Adana, Turkey; [b]Department of Cardiology, Osmaniye State Hospital, Osmaniye, Turkey; [c]Department of Chest Diseases, Osmaniye State Hospital, Osmaniye, Turkey; [d]Department of Cardiology, Faculty of Medicine, Kafkas University, Kars, Turkey

Highlights of the Study

- Right ventricular (RV) dysfunction detected by echocardiography is a predictor of increased mortality in patients with chronic obstructive pulmonary disease (COPD).
- This study demonstrates an association between the RS time in electrocardiograms (ECGs) and the RV function measured by echocardiography.
- Measuring the RS time duration with an ECG can help identify high-risk COPD patients with RV dysfunction.

Keywords
Chronic obstructive pulmonary disease · Electrocardiography · Right ventricular dysfunction · RS time

Abstract

Objective: The occurrence of right ventricular (RV) dysfunction in chronic obstructive pulmonary disease (COPD) results in an increased risk of mortality. We aimed to study the diagnostic value of RS time in the recognition of COPD patients with RV dysfunction. ***Methods:*** 120 consecutive COPD patients were divided into two groups, patients with and without RV dysfunction, and compared them in terms of parameters including RS time. RS time was defined as the longest interval from the beginning of the QRS complex to the nadir of the S- or S′-wave in the inferolateral leads on an electrocardiogram. ***Results:*** RV dysfunction was observed in 36% of consecutive COPD patients with a mean age of 63.4 ± 9.8 years (83.3% male) and a mean forced expiratory volume in 1 s of 1.51 ± 0.62 lt. The heart rate, right QRS axis deviation frequency, S1S2S3 pattern frequency, and RS time ($p < 0.01$) were significantly higher in the patients with RV dysfunction than in those without. Body surface area, heart rate, and RS time ($p < 0.001$) were independent predictors of an RV dysfunction. An ROC analysis showed that the best RS time cut-off value for the prediction of RV dysfunction was 60 ms with a sensitivity of 81.4% and a specificity of 74.0%. ***Conclusion:*** In patients with COPD, RS time prolongation, which can be easily and quickly determined from the electrocardiogram, may be a marker for RV dysfunction.

Karger@karger.com
www.karger.com/mpp

Karger
OPEN ACCESS

Correspondence to:
Ibrahim Yildiz, ibrahimyildiz79@yahoo.com

Introduction

Chronic obstructive pulmonary disease (COPD), a progressive chronic disease of the lungs and airways, is accompanied by an increased inflammatory response to noxious stimuli [1]. In patients with COPD, there is a close anatomical and functional relationship of the right ventricle (RV) with the lung (where pulmonary vasoconstriction, structural changes, or vascular remodeling in the pulmonary arteries cause an increase in pulmonary vascular resistance) and RV afterload that can result in the development of RV dysfunction [2, 3]. Although many factors play a role in this complicated interaction, hypoxemia is the main factor [2].

Morbidity and/or mortality increase as RV dysfunction develops in COPD patients. RV dysfunction is significantly correlated with the overall survival rate and hospital-free survival rate, and it adversely affects exercise capacity [4–6]. The prevalence of RV dysfunction increases with severity of airway obstruction, occurring in 40% of patients with a forced expiratory volume in 1 s (FEV_1) value less than 1 L and in 70% of patients with a FEV_1 value less than 0.6 L [7]. Differentiating COPD from concomitant RV dysfunction can be difficult. Moreover, symptoms and physical signs may have limited value in the assessment of RV dysfunction in patients with COPD [8, 9]. Also, in the advanced RV dysfunction stage, related symptoms and physical signs, such as leg edema or ascites, may be absent [9].

In clinical practice, echocardiography is the standard imaging modality for assessing RV function and identifying impaired RV function [10]. However, family physicians, pulmonologists, primary care physicians, emergency physicians, general practitioners, and internists usually do not have an echocardiography device to evaluate RV functions. The electrocardiogram (ECG) is a widely used noninvasive test, and it can provide rapid data on the structure and functions of the right side of the heart [11–14]. Several electrocardiographic parameters, including QRS duration and QTc duration, have been associated with RV dysfunction [11, 12]. In addition, the S1S2S3 pattern, S1Q3T3 pattern, low-voltage QRS, and right QRS axis deviation have been defined as some of the electrocardiography findings reflecting RV dysfunction and chronic cor pulmonale [13, 14].

RS time, a new ECG parameter, is defined as the duration from the onset of QRS to the nadir of the S-wave, which may become prolonged due to stretching and widening of the S-wave. RS time was recently introduced as a criterion for the detection of acute pulmonary embolism [15]. Although its relationship with RV overload has been shown in patients with pulmonary embolism, the relationship between RV dysfunction and RS time in COPD patients is unknown. The aim of this study was to investigate the relationship between RV functions and RS time in COPD patients.

Materials and Methods

Study Patients

This study was conducted on consecutive patients with COPD admitted to a chest disease outpatient clinic from November 2020 to April 2021. The patients were evaluated by a pulmonologist experienced in COPD; cardiologists did not evaluate the patients in this clinic. A total of 187 patients with COPD admitted from November 2020 to April 2021 were screened. We excluded 9 patients with a history of coronary artery disease, 4 with atrial fibrillation, 20 with inadequate echocardiographic image quality, 4 with ejection fraction of less than 50%, 10 with signs of systemic venous congestion of right heart failure, 16 with right bundle branch block, 3 with left bundle branch block, and one with a pacemaker rhythm. The remaining 120 patients with COPD constituted the study population. Signs of systemic venous congestion of right heart failure were defined as distended and prominent jugular veins, significant peripheral edema, hepatomegaly, or ascites [16].

Patients were classified into two groups based on their echocardiographic RV dysfunction parameters (tricuspid annular plane systolic excursion [TAPSE] < 17 mm, tricuspid annulus peak systolic velocity [Sm] < 9.5 cm/s, RV myocardial performance index <0.54, and RV fractional area change [RVFAC] < 35%). In these two groups, patients without RV dysfunction or patients with RV dysfunction were compared [17, 18]. Patients confirmed to have COPD on the basis of pulmonary function tests were referred to the cardiology outpatient clinic for cardiological evaluation after blood samples were collected. Echocardiographic examinations were performed by an experienced cardiologist blinded to the electrocardiographic records and pulmonary function tests of the patients. Among the patients who were evaluated cardiologically, patients with COPD determined to be eligible for the study were included in the study, and their written informed consent was obtained.

Clinical and Laboratory Data

The age, gender, hypertension, diabetes, and smoking history of the patients and the height and weight values used to calculate the body surface area were recorded for each patient from interviews and medical records. In addition, before the patients were referred to the cardiology outpatient clinic, routine laboratory tests for white blood cell (WBC) count, hemoglobin, C-reactive protein, blood glucose, and creatinine levels were performed.

Spirometric Evaluation

Based on the guidelines of the American Thoracic Society, the spirometric re-evolution/new evolution test was performed by a pulmonologist on all the patients who were followed up or diagnosed with COPD in the chest disease outpatient clinic [19]. In patients with peculiar symptoms and significant exposure to nox-

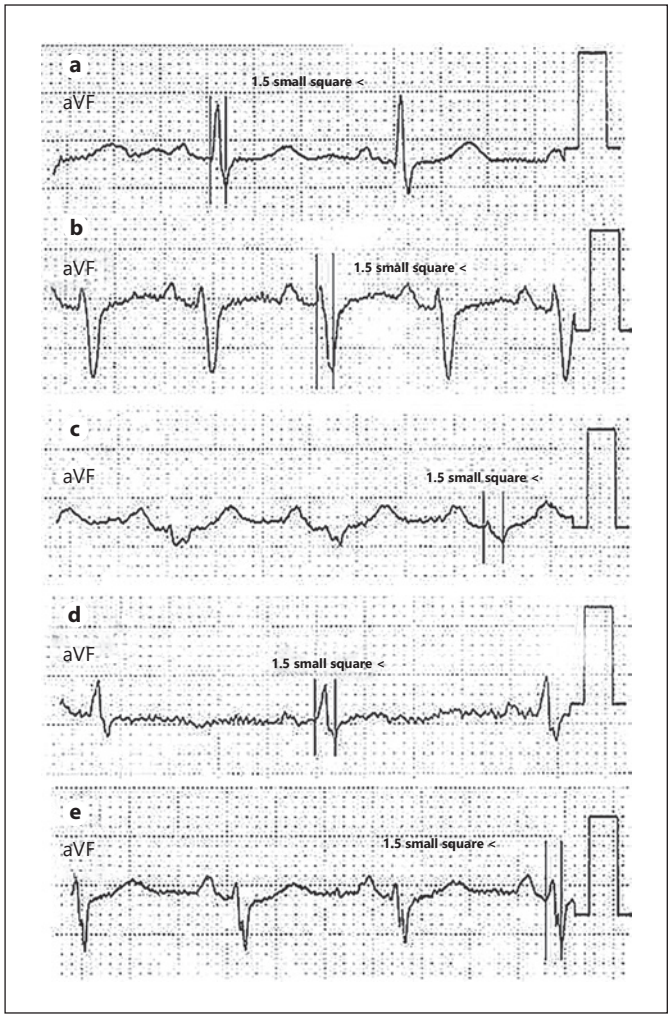

Fig. 1. a–e Measurement of RS time in five different COPD patients with RV dysfunction.

ious stimuli, the presence of postbronchodilator FEV_1/forced vital capacity (FVC) < 0.70 was taken as the definition of COPD, and the diagnosis of COPD was confirmed [20]. FEV_1/FVC ratios and FEV_1 values were obtained from the pulmonary function tests of the patients.

Electrocardiographic Assessment

ECGs were recorded at a speed of 25 mm/s and a voltage of 10 mm/mV. All ECG papers were scanned, loaded to a computer, and analyzed with ImageJ Java image processing program (imagej.nih.gov/ij/) for morphological evaluation and measurement of intervals. Electrocardiographic assessments were made by two independent cardiologists, blinded to the other data of the patients, with the option of consulting a third experienced cardiologist for final decision in the case of disagreement.

The ECGs were examined for heart rate, right QRS axis deviation, low voltage in limb leads, QRS fragmentation, S1Q3T3 pattern, and S1S2S3 pattern. Right QRS axis deviation was defined as the QRS axis between +90° and +180°. Low voltage in limb leads was defined as a QRS amplitude of 5 mm or less at any of the limb leads (I, II, III, AVF, AVR, AVL). QRS fragmentation was defined as the presence of notches in the R- or S-wave in at least two contiguous leads. The S1Q3T3 pattern was defined as the presence of any S-wave in lead I, Q-wave (>1.5 mm deep) in lead III, and T-wave inversion in lead III. The S1S2S3 pattern was defined as the presence of a terminal S-wave in all leads I, II, and III. When all the ECG leads were evaluated, the longest time from the beginning of the QRS complex to the J point was determined as the QRS duration. RS time was defined as the interval from the beginning of the QRS complex to the nadir of the S- or S′-wave, measured in the inferolateral leads (I, II, III, AVF, V4, V5, V6, and AVL) (Fig. 1). The longest duration of RS time measured from the inferolateral leads was determined as the RS time [15]. The R-wave peak time (RWPT) was defined as the interval from the beginning of the QRS complex until the peak of the R- or r′-wave, measured in the inferolateral leads. The longest RWPT measured from the inferolateral leads was determined as $RWPT_{MAX}$.

Echocardiographic Assessment

Transthoracic echocardiographic examinations were performed by an experienced cardiologist blinded to patients' data, using an EPIQ 7 ultrasound system (Philips Medical Systems, Bothell, WA, USA). Two-dimensional, Doppler, and tissue Doppler echocardiographic measurements were done in accordance with guidelines of the American Society of Echocardiography [18].

The RV end diastolic and systolic areas were measured in the apical 4-chamber view by tracing the RV annulus, free wall, apex, and interventricular septum endocardium, including the trabeculae in the diastole and systole, respectively. The RVFAC was then calculated by using the described formula ([end diastolic area – end systolic area]/end diastolic area *x* 100). The TAPSE was measured in the apical 4-chamber view by positioning the M-mode cursor to the intersection of the tricuspid valve plane and the RV free wall to find the maximum displacement of the tricuspid annulus during systole. The pulsed Doppler sample volume was placed at the tips of the tricuspid valve leaflets to measure the peak velocity of the early diastolic trans-tricuspid flow (E) and the peak velocity of the late diastolic trans-tricuspid flow (A). The pulsed tissue Doppler sample volume was placed at the lateral corner of the tricuspid annulus in the apical 4-chamber view to measure the tricuspid annulus peak early diastolic velocity (Em), tricuspid annulus peak late diastolic velocity (Am), and Sm. RV isovolumetric contraction time (IVCT) was measured between the cessation of Am-wave and the onset of Sm-wave; RV ejection time (ET) was measured between the onset and cessation of Sm-wave; RV isovolumetric relaxation time (IVRT) was measured between the cessation of Sm-wave and onset of Em-wave. The RV myocardial performance index was calculated as the sum of IVCT and IVRT divided by ET (IVCT + IVRT)/(ET) [21].

Statistical Analysis

SPSS Statistics for Windows, version 17.0 (SPSS Inc., Chicago, IL, USA) was used for the statistical analyses. A statistically significant difference was accepted as having a p value of less than 0.05. We compared the characteristics of patients with and without RV dysfunction. Normality of the data distribution was evaluated with a histogram and analyzed using the Kolmogorov-Smirnov

Table 1. Clinical, laboratory, and spirometry findings

Clinical and laboratory findings	RV dysfunction						
	all patients (n = 120)		patients without RV dysfunction (n = 77)		patients with RV dysfunction (n = 43)		p value*
	mean	SD	mean	SD	mean	SD	
Age, years	63.4	9.8	61.8	10.3	66.2	8.1	0.02
Body surface area, m^2	1.82	0.17	1.84	0.17	1.77	0.17	0.03
WBC count, $10^3/\mu L$	10.66	3.94	10.20	3.82	11.49	4.06	0.05
Hemoglobin, g/dL	14.0	1.9	14.0	1.9	14.0	1.8	0.81
Blood glucose, mg/dL	116.7	48.2	119.8	51.3	111.2	42.0	0.51
Creatinine, mg/dL	0.9	0.4	0.9	0.5	0.8	0.3	0.27
	%	*n*	%	*n*	%	*n*	p value**
Male gender	83.3	100	83.1	64	83.7	36	0.93
Diabetes	16.7	20	14.3	11	20.9	9	0.35
Hypertension	32.5	39	29.9	23	37.2	16	0.41
Smoking	89.2	107	88.3	68	90.7	39	0.69
	median	IQR	median	IQR	median	IQR	p value***
C-reactive protein, mg/dL	4.81	3.13–11.80	4.72	3.35–10.30	5.24	3.12–15.20	0.96
	mean	SD	mean	SD	mean	SD	p value*
Spirometry findings							
FEV_1/FVC ratio	0.58	0.09	0.62	0.06	0.52	0.10	<0.01
FEV_1 (lt)	1.51	0.62	1.77	0.58	1.04	0.35	<0.01

FEV_1, forced expiratory volume in 1 s; FVC, forced vital capacity; IQR, interquartile range; SD, standard deviation; WBC, white blood cell. * Calculated with Student's t test. ** Calculated with the χ^2 test and Fisher's exact test. *** Calculated with the Mann-Whitney U test.

and Shapiro-Wilk tests. Normally distributed continuous variables were presented in the tables as means and standard deviations. The continuous variables without normal distributions are presented in tables as medians (interquartile ranges). The two groups were compared using the Student's t test for variables with normal distributions or the Mann-Whitney U test for the variables without normal distributions. Numbers and percentages were used for the presentation of the categorical variables, and the groups were compared using the χ^2 or Fisher's exact test, as appropriate. Pearson's correlation coefficient test was performed to study the correlation between RS time and echocardiographic RV dysfunction parameters. Multivariable logistic regression analyses were performed with the variables that showed significant differences in the univariate analysis to determine whether the RS time was an independent predictor of RV dysfunction. The effect size (Cohen's d) and power value (1−β) of the study for the RS time were calculated using the G*Power software. The effect size and power value were 0.408 and 0.873, respectively. In order to define the best RS time cutoff value for predicting RV dysfunction, an analysis of the receiver operating characteristic curve was performed using Youden's J statistic.

Results

The study population comprised 120 COPD patients with a mean age of 63.4 ± 9.8 years (83.3% male). They were assigned to one of two groups based on whether or not there were findings consistent with RV dysfunction parameters (TAPSE <17 mm, Sm < 9.5 cm/s, tissue Doppler MPI <0.54, and RVFAC <35%) The patients with the presence of one of those parameters were placed in the patients with RV dysfunction group (n = 43), and those with none of those parameters were placed in the patients without RV dysfunction group (n = 77). Table 1 lists the clinical and spirometric, and Table 2 lists echocardiographic and electrocardiographic features of all the patients and each group. There were no statistically significant differences between the groups regarding gender, diabetes mellitus incidence, hypertension incidence, or incidence of smoking. Patients with RV dysfunction were significantly older and had a lower body surface area than

Table 2. Echocardiography and electrocardiography findings

Echocardiography findings	RV dysfunction						
	all patients (n = 120)		patients without RV dysfunction (n = 77)		patients with RV dysfunction (n = 43)		p value*
	mean	SD	mean	SD	mean	SD	
Left ventricular ejection fraction, %	59.0	4.6	59.8	4.2	57.7	5.0	0.03
RV dimension, cm	3.5	0.5	3.4	0.5	3.7	0.5	0.02
Right atrial dimension, cm	4.5	0.6	4.4	0.5	4.7	0.7	0.01
RVFAC, %	45.66	8.26	48.26	7.41	41.00	7.72	<0.01
Trans-tricuspid E, m/s	0.58	0.14	0.57	0.12	0.58	0.16	0.97
Trans-tricuspid A, m/s	0.57	0.14	0.55	0.15	0.61	0.13	0.01
Trans-tricuspid, E/A	1.06	0.33	1.11	0.33	0.97	0.30	0.02
Em, cm/s	11.1	2.7	11.8	2.6	9.7	2.3	<0.01
Am, cm/s	17.0	4.5	16.4	4.0	18.2	5.1	0.03
Sm, cm/s	12.9	2.5	13.9	2.2	11.0	2.0	<0.01
TAPSE, mm	20.4	3.0	21.9	2.3	17.8	2.2	<0.01
RV IVCT, m/s	60.0	12.8	58.9	12.5	61.8	13.2	0.36
RV ET, m/s	259.4	39.3	272.1	31.9	236.7	41.3	<0.01
RV IVRT, m/s	74.9	28.3	65.8	16.2	91.3	37.1	<0.01
RV myocardial performance index	0.52	0.09	0.46	0.04	0.62	0.07	<0.01
PASP, mm Hg	39.1	10.5	34.3	7.3	47.6	10.0	<0.01
Electrocardiography findings	%	n	%	n	%	n	p value**
Right QRS axis deviation	10.0	12	5.2	4	18.6	8	0.02
Low voltage in limb leads	59.2	71	54.5	42	67.4	29	0.17
QRS fragmentation	39.2	47	36.4	28	44.2	19	0.40
S1S2S3 pattern	11.7	14	6.5	5	20.9	9	0.02
S1Q3T3 pattern	10.0	12	9.1	7	11.6	5	0.66
	mean	SD	mean	SD	mean	SD	p value*
Heart rate, beats/min	84.8	16.8	80.3	16.3	92.9	14.6	<0.01
QRS duration, m/s	92.8	11.4	92.0	10.4	94.2	12.9	0.61
RS time, m/s	60.4	10.7	56.4	8.8	67.5	10.1	<0.01
$RWPT_{MAX}$, m/s	44.6	12.6	43.5	12.4	46.4	12.9	0.11

Am, tricuspid annulus peak late diastolic velocity; Em, tricuspid annulus peak early diastolic velocity; PASP, pulmonary artery systolic pressure; RV, right ventricular; RVFAC, right ventricular fractional area change; $RWPT_{MAX}$, maximum R-wave peak time in inferolateral leads; Sm, tricuspid annulus peak systolic velocity; TAPSE, tricuspid annular plane systolic excursion; SD, standard deviation. * Calculated with Student's t test. ** Calculated with the χ^2 test and Fisher's exact test.

patients without RV dysfunction. The laboratory measurements were similar, including WBC count, hemoglobin, creatinine, C-reactive protein, and blood glucose. The FEV_1/FVC ratio and FEV_1 were significantly lower in patients with RV dysfunction than in patients without RV dysfunction (Table 1).

Among the echocardiographic parameters, left ventricular ejection fraction, RVFAC, trans-tricuspid E/A, Em, Sm, TAPSE, and RV ET were significantly lower in patients with RV dysfunction compared to patients without RV dysfunction. In contrast, the RV dimension, right atrial dimension, trans-tricuspid A, Am, RV IVRT, RV myocardial performance index, and pulmonary artery systolic pressure were significantly higher. Trans-tricuspid E and RV IVCT were similar between the groups. Among the electrocardiographic parameters, low voltage in limb leads frequency, QRS duration, QRS fragmentation frequency, S1Q3T3 pattern frequency, and $RWPT_{MAX}$ were similar for the groups. However, heart rate, right QRS axis deviation frequency, S1S2S3 pattern frequency, and RS time (56.4 ± 8.8 m vs. 67.5 ± 10.1 m, $p < 0.01$) were significantly higher in

the patients with RV dysfunction than in those without RV dysfunction.

Pearson's correlation coefficient test of the RS time with echocardiographic RV dysfunction parameters was performed. The RS time exhibited significantly moderate negative correlation with the TAPSE ($r = -0.596$, $p < 0.001$), significantly weak negative correlation with the RVFAC ($r = -0.256$, $p = 0.005$), significantly weak negative correlation with the tricuspid Sm ($r = -0.396$, $p < 0.001$), significantly moderate positive correlation with the RV myocardial performance index ($r = 0.574$, $p < 0.001$).

Independent predictors of RV dysfunction were identified by multivariable logistic regression analyses using the variables, including age, body surface area, heart rate, right QRS axis deviation frequency, S1S2S3 pattern frequency, and RS time, which showed significant differences in the univariate analysis. Low voltage in limb lead frequency and WBC count, which showed a borderline significance in the univariate analysis, were also included in the model. The results showed that body surface area (odds ratio [OR] = 0.004, 95% confidence interval [CI] = 0.000–0.185, $p = 0.004$), heart rate (OR = 1.068, 95% CI = 1.029–1.107, $p < 0.001$), and RS time (OR per 1 m increase = 1.191, 95% CI = 1.109–1.279, $p < 0.001$) were independent predictors of a RV dysfunction. In addition, the RS time was found to be an independent predictor of a RV dysfunction (OR = 1.224, 95% CI = 1.128–1.327, $p < 0.001$), whereas QRS duration was not (OR = 0.947, 95% CI = 0.888–1.009, $p = 0.092$) in the multivariable logistic regression analyses we performed by including QRS duration in the model.

Receiver operating characteristic curve analysis showed that the best RS time cutoff value for the prediction of RV dysfunction was 60 m (1.5 small square on ECG), with a sensitivity of 81.4% and a specificity of 74% (area under the curve = 0.798, 95% CI = 0.715–0.866, $p < 0.001$). RS time 60 m < had a positive predictive value of 63.6% and negative predictive value of 87.7% for the prediction of RV dysfunction.

Discussion

We report here that electrocardiographic parameters, such as heart rate, right QRS axis deviation frequency, S1S2S3 pattern frequency, and RS time, were higher in patients with COPD with echocardiographically defined RV dysfunction than in patients without RV dysfunction. Moreover, we identified RS time, heart rate, and BSA as independent predictors of RV dysfunction.

The prolongation of RS time may be attributed to the structural changes of the heart. Lung diseases, such as COPD, reportedly cause widening and slurring of the S-waves in the leads conforming to the inferolateral regions on the ECG [22]. Superiorly and rightward-oriented late vectors have been implicated in the formation of this type of S-wave, and the possible source of these late vectors is attributed to the hypertrophied crista supraventricularis. The S1S2S3 pattern, which can reflect chronic cor pulmonale, also reportedly depends on superiorly and rightward-oriented late vectors opposed to the electrical forces of the ventricular free wall [23]. It is conceivable that the stretching and widening of the S-wave affects the duration from the beginning of QRS to the nadir of the S-wave, called the RS time. The prolongation of RS time in diseases that affect RV structure does not seem to be innocent. Indeed, in previous studies, prolongation of RS time has been found to be a predictor for pulmonary embolism and to be associated with short-term mortality after pulmonary embolism [15, 24]. Although the incidence of the S1S2S3 pattern was more common in patients with RV dysfunction than without RV dysfunction, multivariable analysis showed that the S1S2S3 pattern was not significant in predicting RV dysfunction. However, RS time prolongation was significantly associated with RV dysfunction. In addition to the prominence of superiorly and rightward-oriented late vectors in RV dysfunction, RV strain due to RV dysfunction may have caused a conduction delay in the ECG and altered the QRS complexes through structural changes in the myocardium [25, 26].

QRS duration was shown to be associated with RV dysfunction [11, 12]. However, in our multivariable analysis, the RS time was found to be an independent predictor of RV dysfunction, in contrast to the QRS duration. One explanation is that previous studies showing the relationship between QRS duration and RV dysfunction were conducted in patients receiving operations for congenital heart disease, whereas our study was conducted in patients with COPD.

In clinical practice, RS time may enable physicians to send COPD patients (without overt clinical signs of right heart failure and with suspected RV dysfunction) to the cardiology department for definitive diagnosis using echocardiography. The increasing demand for echocardiograms in high-patient-volume clinics may be reduced by selecting patients for echocardiography based on RS time prolongation and a heightened suspicion of disease. Thus, RS time may facilitate the prediction of early RV dysfunction detection, which may enable us to provide information about the prognosis and to take necessary

measures (such as better correction of hypoxemia and hypoxia and the administration of appropriate COPD-specific therapies) to stop or reverse the process before the signs of congestive heart failure develop [9].

Our study has some limitations. First, our study population consisted of a relatively small number of patients so further studies with larger numbers of patients are needed. Second, the patients were not questioned in detail about their symptoms as the scope of this study did not include demonstrating the superiority of RS time to symptoms related to heart failure in determining RV dysfunction as it is already known that COPD symptoms frequently overlap with the symptoms defined by the Framingham criteria for the diagnosis of heart failure [8]. Third, while cardiac magnetic resonance imaging is the gold standard for estimating RV functions in our study, we were limited to examining the RV functions of the patients with echocardiography due to cost and ethical considerations. In addition, we excluded patients with right and left bundle branch blocks from our study to reduce the impact of confounding variables as the disturbances in the conduction system may have already led to prolongation of the RS time. Finally, while all patients with coronary artery disease could not be excluded, patients with known coronary artery disease proven by angiography were excluded from the study.

Conclusion

Prolonged RS time is independently associated with RV dysfunction in COPD patients. Issues such as the high probability and the poor prognosis of RV dysfunction in COPD patients can be addressed by quickly and easily evaluating the RS time from the ECG, which is a cheap and widely used tool that is easy to use, even by general practitioners or physicians. The widespread clinical use of RS time as a screening test for prediction of RV dysfunction in COPD patients may allow a closer follow-up of these patients.

Statement of Ethics

This study protocol was approved by the Ethics Committee of the Kafkas University Medical Faculty and the Osmaniye Provincial Health Directorate (Number: 77378720-774.99 Date: June 17, 2020). This study was conducted under the principles of the Declaration of Helsinki. Written informed consent was obtained from all enrolled patients.

Conflict of Interest Statement

None.

Funding Sources

The authors received no financial support for the research, authorship, and/or publication of this article.

Author Contributions

Ibrahim Yildiz, Ibrahim Rencuzogullari, and Yavuz Karabag developed the study design. Ibrahim Yildiz, Husamettin Sazlidere, and Mehmet Sait Gurevin reviewed the literature. Ibrahim Yildiz, Husamettin Sazlidere, Pinar Ozmen Yildiz, and Mehmet Sait Gurevin collected data. Ibrahim Rencuzogullari and Yavuz Karabag analyzed and interpreted data. İbrahim Yıldız and Pinar Ozmen Yildiz wrote the paper. All the authors reviewed and approved the final version of the manuscript.

Data Availability Statement

The data of this study are not publicly available as they contain information that could compromise the privacy of research participants but are available from the corresponding author upon reasonable request.

References

1 Vestbo J, Hurd SS, Agustí AG, Jones PW, Vogelmeier C, Anzueto A, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. Am J Respir Crit Care Med. 2013 Feb 15;187(4):347–65.

2 Kent BD, Mitchell PD, McNicholas WT. Hypoxemia in patients with COPD: cause, effects, and disease progression. Int J Chron Obstruct Pulmon Dis. 2011;6:199–208.

3 Himelman RB, Struve SN, Brown JK, Namnum P, Schiller NB. Improved recognition of cor pulmonale in patients with severe chronic obstructive pulmonary disease. Am J Med. 1988 May;84(5):891–8.

4 Tanaka Y, Hino M, Mizuno K, Gemma A. Evaluation of right ventricular function in patients with COPD. Respir Care. 2013 May;58(5):816–23.

5 Almagro P, Barreiro B, Ochoa de Echaguen A, Quintana S, Rodríguez Carballeira M, Heredia JL, et al. Risk factors for hospital readmission in patients with chronic obstructive pulmonary disease. Respiration. 2006;73(3):311–7.

6 Cuttica MJ, Shah SJ, Rosenberg SR, Orr R, Beussink L, Dematte JE, et al. Right heart structural changes are independently associated with exercise capacity in non-severe COPD. PLoS One. 2011;6(12):e29069.

7 Klinger JR, Hill NS. Right ventricular dysfunction in chronic obstructive pulmonary disease. Evaluation and management. Chest. 1991 Mar;99(3):715–23.
8 Hawkins NM, Petrie MC, Jhund PS, Chalmers GW, Dunn FG, McMurray JJ. Heart failure and chronic obstructive pulmonary disease: diagnostic pitfalls and epidemiology. Eur J Heart Fail. 2009 Feb;11(2):130–9.
9 Kolb TM, Hassoun PM. Right ventricular dysfunction in chronic lung disease. Cardiol Clin. 2012 May;30(2):243–56.
10 Schneider M, Aschauer S, Mascherbauer J, Ran H, Binder C, Lang I, et al. Echocardiographic assessment of right ventricular function: current clinical practice. Int J Cardiovasc Imaging. 2019 Jan;35(1):49–56.
11 Plymen CM, Hughes ML, Picaut N, Panoulas VF, Macdonald ST, Cullen S, et al. The relationship of systemic right ventricular function to ECG parameters and NT-proBNP levels in adults with transposition of the great arteries late after Senning or Mustard surgery. Heart. 2010 Oct;96(19):1569–73.
12 Alonso P, Andrés A, Rueda J, Buendía F, Igual B, Rodríguez M, et al. Value of the electrocardiogram as a predictor of right ventricular dysfunction in patients with chronic right ventricular volume overload. Rev Esp Cardiol. 2015 May;68(5):390–7.
13 Incalzi RA, Fuso L, De Rosa M, Di Napoli A, Basso S, Pagliari G, et al. Electrocardiographic signs of chronic cor pulmonale: a negative prognostic finding in chronic obstructive pulmonary disease. Circulation. 1999 Mar 30;99(12):1600–5.
14 Kok-Jensen A. Simple electrocardiographic features of importance for prognosis in severe chronic bronchial obstruction. Scand J Respir Dis. 1975;56(5):273–84.
15 Rencuzogullari I, Çağdaş M, Karabağ Y, Karakoyun S, Çiftçi H, Gürsoy MO, et al. A novel ECG parameter for diagnosis of acute pulmonary embolism: RS time – RS time in acute pulmonary embolism. Am J Emerg Med. 2019 Jul;37(7):1230–6.
16 D'Andrea A, Salerno G, Scarafile R, Riegler L, Gravino R, Castaldo F, et al. Right ventricular myocardial function in patients with either idiopathic or ischemic dilated cardiomyopathy without clinical sign of right heart failure: effects of cardiac resynchronization therapy. Pacing Clin Electrophysiol. 2009 Aug;32(8):1017–29.
17 Naksuk N, Tan N, Padmanabhan D, Kancharla K, Makkar N, Yogeswaran V, et al. Right ventricular dysfunction and long-term risk of sudden cardiac death in patients with and without severe left ventricular dysfunction. Circ Arrhythm Electrophysiol. 2018 Jun;11(6):e006091.
18 Lang RM, Badano LP, Mor-Avi V, Afilalo J, Armstrong A, Ernande L, et al. Recommendations for cardiac chamber quantification by echocardiography in adults: an update from the American Society of Echocardiography and the European Association of Cardiovascular Imaging. Eur Heart J Cardiovasc Imaging. 2015 Jan;16(1):233–70.
19 Standardization of Spirometry, 1994 Update. American Thoracic Society. Am J Respir Crit Care Med. 1995 Sep;152(3):1107–36.
20 Rabe KF, Hurd S, Anzueto A, Barnes PJ, Buist SA, Calverley P, et al. Global strategy for the diagnosis, management, and prevention of chronic obstructive pulmonary disease: GOLD executive summary. Am J Respir Crit Care Med. 2007 Sep 15;176(6):532–55.
21 Zimbarra Cabrita I, Ruisanchez C, Dawson D, Grapsa J, North B, Howard LS, et al. Right ventricular function in patients with pulmonary hypertension; the value of myocardial performance index measured by tissue Doppler imaging. Eur J Echocardiogr. 2010 Sep;11(8):719–24.
22 Burch GE, Depasquale NP. The electrocardiographic diagnosis of pulmonary heart disease. Am J Cardiol. 1963 May;11:622–38.
23 Delise P, Piccolo E, D'Este D, De Piccoli B, Raviele A, Di Pede F, et al. Electrogenesis of the S1S2S3 electrocardiographic pattern. A study in humans based on body surface potential and right ventricular endocardial mapping. J Electrocardiol. 1990 Jan;23(1):23–31.
24 Gümüşdağ A, Burak C, Süleymanoğlu M, Yesin M, Tanık VO, Karabağ Y, et al. The predictive value of RS time for short term mortality in patients with acute pulmonary embolism. J Electrocardiol. 2020 Sep–Oct;62:94–9.
25 Larssen MS, Steine K, Hilde JM, Skjørten I, Hodnesdal C, Liestøl K, et al. Mechanisms of ECG signs in chronic obstructive pulmonary disease. Open Heart. 2017 Mar 22;4(1):e000552.
26 Park DH, Cho KI, Kim YK, Kim BJ, You GI, Im SI, et al. Association between right ventricular systolic function and electromechanical delay in patients with right bundle branch block. J Cardiol. 2017 Nov;70(5):470–5.