

The late diastolic velocity (A) was higher in the SPAFE group than the WAR group ($p=0.043$). Other transthoracic echocardiography findings were similar among the groups. Pmax, Pd and heart rate values were not significantly different among the groups. The frequency of fQRS morphology was significantly higher in the SAR and SPAFE groups than in the WAR group ($p=0.002$) (Table II). This significance continued in the logistic regression analysis in the SAR group, and fQRS morphology was determined as an independent predictor of SAR (odds ratio=0.056; 95% CI, 0.006–0.548; $p=0.013$). However, after the multivariate analysis, the statistical significance in the SPAFE group was lost (Table III).

DISCUSSION

Our study showed that the presence of fQRS morphology in 12-lead ECG may be used as a predictor to predict SAR risk. Additionally, a statistically significant relationship was determined in our study between fQRS morphology and SPAFE.

Chronic renal failure is related to aging, coronary artery disease, congestive heart failure, hypertension, widened pulse pressure, diabetes mellitus, left ventricular hypertrophy, and valvular heart disease, all of which also cause chronic pathophysiological changes providing basis for development of AF^{1,3,16}. Moreover, plasma electrolyte changes, abnormalities in catecholamine levels, effects of dialysate composition, sudden hemodynamic and metabolic changes caused by the hemodialysis procedure, pre-dialysis systolic blood pressure, serum albumin levels, and duration of dialysis are factors that are likely to increase the risk of AF^{17,18}.

Hemodialysis contributes to the development of structural disorders such as diastolic dysfunction and atrial remodeling. These structural disorders are associated with the development of atrial fibrillation. Transthoracic

echocardiography is a non-invasive test that can detect impairments in cardiac structure and diastolic function in the early period. The standard echocardiographic measurements were in normal ranges in all three groups. Furthermore, while the difference was not statistically significant, the LA measurement was increased in the SAR and SPAFE groups in comparison to the WAR group. The amplitude of A wave was higher in SPAFE and SAR groups than in WAR group. However, this height was statistically significant only in the SPAFE group. The E/A ratio, which is one of the indicators of diastolic dysfunction, was statistically insignificant, but it was lower in the SAR and SPAFE groups. These findings do not show marked atrial remodeling and diastolic dysfunction, but may be related to the onset of these disorders. In addition, these results are not compatible with previous studies results^{1,2,11}. The small working volume and the patients' sinus rhythm may explain this incompatibility. Moreover, our study was a retrospective study, and there were no atrial volume and tissue doppler measurement data. For this reason, the relationship between hemodialysis-related structural changes and AF risk could not be optimally examined. It has been reported in clinical studies that the duration of HD treatment duration is an independent risk factor for the development of AF^{1,2}. In this study, it was observed that the application time of HD treatment was longer in the SPAFE and SAR groups than in the WAR group. However, this length was statistically significant only in the SPAFE group. This showed that increased HD duration and incidence of SAR and SPAFE may be associated. Previous studies reported the AF incidence in HD patients to be 7-27%¹. This broad range in incidence may have been explained by the variations in age groups, duration of renal replacement therapy, other clinical characteristics, and methodology to record AF. AF is seen in HD patients usually in the form of

paroxysmal AF¹⁹. The ACC / AHA 2006 guidelines reported a threshold of 30 seconds for the diagnosis of paroxysmal AF, while SAR lasting shorter than 30 seconds may be an indicator of longer episodes²⁰. SAR and SPAFE are a risk factor for noticeable AF that may emerge in the future⁶⁻⁸. In this study, episodes consisting of at least 3 irregular consecutive atrial runs were determined in 18 of the 74 patients (24%). Among these patients, 6 (33%) and 12 (66%) respectively showed SPAFE and SAR. The Holter ECG recording time monitored in this study was 24 hours. It is also known that longer durations of recording increase the detection sensitivity of arrhythmias²¹. The load of arrhythmia in our study may have been reflected suboptimally due to the Holter ECG recording time and study volume.

Studies have shown that P wave abnormalities are associated with the development of AF (Pmin, Pmax, and Pd)^{22,23}. In studies evaluating this relationship in hypertensive patients, conflicting results were found considering Pmax, but a decreased Pmin value was found to be an independent predictor of AF²². In this study, Pd and Pmax values were similar between the groups. The Pmin value was lower in the SPAFE and SAR groups, but this difference was not found to be statistically significant. The demographic characteristics of the HD population (age, comorbidities), small working volume and the effects of hemodialysis on ECGs (ECG parameters can even change before, during, or after hemodialysis) might have caused this conflicting result of our study. The abnormalities of atrial conduction may be related to atrial fibrosis. However, there are additional factors that may increase the tendency to develop AF in HD patients such as changes in volume status and electrolyte levels, generalized micro inflammatory state and metabolic derangements of uremic milieu²⁴.

The presence of fQRS on 12-lead ECG has been related to myocardial fibrosis, ischemia, and

increased inflammatory state²⁵⁻²⁷. Its presence in cardiovascular diseases has also been reported to be associated with sudden cardiac death, lethal ventricular arrhythmias, and increased mortality^{28,29}. Recently, many studies have been conducted to research the relationship between fQRS morphology in ECG and development of AF. It was shown that the presence of fQRS in ECG is an independent predictor of postoperative new-onset AF in patients undergoing coronary artery bypass surgery¹⁰. Temiz et al. showed that fQRS morphology in ECG was an independent predictor of AF development in patients without structural heart disease¹¹. Canpolat et al. also demonstrated that fQRS morphology is significantly related to left atrial scar in patients with permanent AF¹². Another study conducted by Eren et al. revealed that the presence of fQRS morphology may be associated with AF recurrence following electrical cardioversion¹³. What is more, Yesin et al. reported that the presence of fQRS morphology in STEMI patients is a significant predictor of AF that may develop after primary coronary intervention¹⁴. The role of fQRS morphology in development of AF has not been explained clearly. Advanced ventricular fibrosis leading to an increase in left ventricular end-diastolic pressure, then increased left atrial pressure and left atrial dilatation, and finally, atrial fibrosis are the possible events providing a basis for development of AF. Additionally, acute hemodynamic and metabolic changes that are likely to occur during the hemodialysis procedure may contribute to the increased risk of AF development in HD patients. This study showed that fQRS morphology in HD patients is independently associated with SAR detected from Holter ECG recordings. Moreover, according to the findings of this study, the presence of fQRS morphology may be associated with the risk of SPAFE. Thus, in hemodialysis patients, fQRS morphology is associated with increased risk of AF, and it may

be useful in distinguishing patients who are under a high risk of AF. Furthermore, for investigating the predictive value of fQRS morphology in terms of the presence of SPAFE in hemodialysis patients, this study may provide an inspiration for prospective research designs with a broader volume and longer Holter recording durations.

Limitations

The main limitation of the study was that the study protocol was retrospective, the volume of the study was limited, and the Holter ECG recording duration was not long enough.

CONCLUSION

To the best of our knowledge, this study is the first study that investigated the relationship between fQRS morphology and AF risk in HD patients. According to the results of the study, the presence of fQRS morphology is associated with increased risk of AF development in HD patients. fQRS morphology may be an accessible, inexpensive, and non-invasive determining parameter that could be used to distinguish those with a high risk of AF development among HD patients and for early intervention that is important in preventing AF and its complications in HD patients.

Ethics Committee Approval: The research protocol in line with the Helsinki Declaration was approved by the local ethics committee (Approval Date: 05.05.2019; Protocol No:2019/09/02).

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