ORIGINAL ARTICLE

CORRELATION OF SIGNAL AVERAGED ECG PARAMETERS WITH ARTERIAL BLOOD PRESSURE IN HYPERTENSIVE PATIENTS

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Background: Signal averaged ECG is a high resolution electrocardiography which detects ventricular late potentials in patients susceptible to ventricular arrhythmias. Ventricular late potentials are identified on the basis of three parameters detected on signal averaged ECG. This study was planned to determine the correlation of signal averaged ECG parameters with arterial blood pressure in hypertensive patients. **Methods:** Sixty-four patients with systemic arterial hypertension were enrolled in the study. Patients with acute or old myocardial infarction, diabetes mellitus, cerebrovascular accident, heart failure, structural heart disease, bundle branch block and cardiomyopathies were excluded from the study. DMS 300 4L Holter monitors were used to obtain 3 channel signal averaged ECG recording. CardioScan® premium luxury software was used for analysis of ventricular late potentials. **Results:** There were 49 male and 15 female patients (n=64) with mean age 60±11.83 years. Eleven patients (17.2%) had ventricular late potentials, whereas 53 (82.8%) were without them. The mean values for filtered QRS complex, low amplitude signals, root mean square voltage and noise were 108.52±23.63 ms, 28.81±20.78 ms, 92.17±51.02 μv and 0.29±0.25 μv respectively. Blood pressure was significantly and positively correlated with filtered QRS complex ($p<0.001$). The correlation with low amplitude signals and root means square voltage was not significant ($p>0.05$). **Conclusion:** Patients with higher systemic arterial blood pressure are at greater risk of developing ventricular late potentials which are reflective of ventricular arrhythmias. In hypertensive patients the arrhythmogenesis seems to be more related to duration of the cardiac signal compared to its voltage.

Keywords: Ventricular late potentials, signal averaged ECG, systemic arterial hypertension

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INTRODUCTION

The term 'signal averaged electrocardiography' incorporates any technique in which multiple electric signals from the heart are averaged to improve the signal to noise ratio in order to reveal ventricular late potentials.[1] Three bipolar orthogonal leads, XYZ are used which represent horizontal, sagittal and coronal planes respectively. The leads are recorded, averaged, filtered and combined into a vector magnitude called the filtered QRS complex. Analysis of the filtered QRS complex characteristically includes filtered QRS duration (fQRS) greater than 114 ms, low amplitude signals (LAS) under 40 μv in the terminal QRS complex greater than 38 ms and root mean square (RMS) voltage in the terminal 40 ms less than 20 μv.[2]

Hypertension is a major health problem with an increasing prevalence worldwide. It is considered a silent killer because of its symptomless proceedings during pathogenesis. Hypertension is considered a major cause of morbidity and mortality worldwide.[3] Systemic arterial hypertensions is a strong predictor of ventricular arrhythmias. Ventricular arrhythmias range from benign premature ventricular ectopic beats to fatal ventricular fibrillation which may lead to sudden cardiac death. Studies have shown that the potential for sudden cardiac death is very high in patients with systemic arterial hypertension.[4]

Ventricular late potentials are low amplitude, high frequency signals present in the terminal part of QRS complex that may extend up to a variable length in ST segment.[5] They are the non-invasive markers of myocardial tissue damage. Increased arterial blood pressure in hypertension results in myocardial fibrosis, a high resistivity area having delayed conduction velocity and prolonged action potential duration. This affects the electro-cardiographic signals between the end of QRS complex and the initial part of ST segment thus generating these low voltage fractionated signals. Detection of ventricular late potentials in hypertensive patients provides a practical and cost effective method to identify the possible electrophysiological substrate underlying the life threatening ventricular arrhythmias which may result in sudden cardiac death.[6] In-depth knowledge about pathophysiology of ventricular arrhythmias developing in patients with hypertension is important because it can significantly affect the prognosis and management of the disease.

The current study was planned to determine the correlation of signal averaged ECG parameters with arterial blood pressure in hypertensive patients. Results of the study would provide an insight into the probable

mechanisms of disturbed electrical activity within ventricular myocardium in these patients. It will prove to be helpful to identify the hypertensive patients who are at high risk of sudden cardiac death due to ventricular arrhythmias. This may also help to devise therapeutic strategies to reduce fatal arrhythmic events in susceptible patients suffering from chronic hypertension.

MATERIAL AND METHODS

This 'cohort retrospective' study was conducted at the department of Cardiac Electrophysiology, Armed Forces Institute of Cardiology in collaboration with Army Medical College, Rawalpindi. An official approval was obtained prior to commencement of the study from medical ethics committee of Army Medical College. Written and informed consent was taken from all the patients included in the study. Sixty-four patients with systemic arterial hypertension were recruited through non-probability purposive sampling. Patients with acute or old myocardial infarction, diabetes mellitus, cerebrovascular accident, heart failure, structural heart disease, bundle branch block and cardiomyopathies were excluded from the study.

The patients were divided into two groups on the basis of presence or absence of left ventricular hypertrophy. Group I comprised of 32 hypertensive patients with left ventricular hypertrophy whereas group II included 32 hypertensive patients without left ventricular hypertrophy. Selected patients were requested to visit Electrophysiology Department of AFIC for Holter monitoring in order to perform signal averaged ECG. Signal averaged ECG data were transferred to the computer and edited with the help of DMS CardioScan® software. Time domain analysis was used to analyse the cardiac signal. Ventricular late potentials were detected through analysis of filtered QRS complex which characteristically included duration of the filtered QRS complex (fQRS) greater than 114 ms, low amplitude signals (LAS) under 40 μv in the terminal QRS complex greater than 38 ms and root mean square (RMS) voltage in the terminal 40 ms less than 20 μv. Ventricular late potentials were considered positive if any two out of three criteria were fulfilled.

Data were analysed using SPSS-22. Qualitative variables were presented as frequency and percentages whereas quantitative variables as mean and standard deviation. Alpha value was kept at 0.05 at confidence level of 95%.

RESULTS

There were 49 male and 15 female patients (n=64) with mean age of 60±11.83 years. Eleven patients (17.2%) had ventricular late potentials whereas 53 (82.8%) were without them as illustrated in Figure-1.

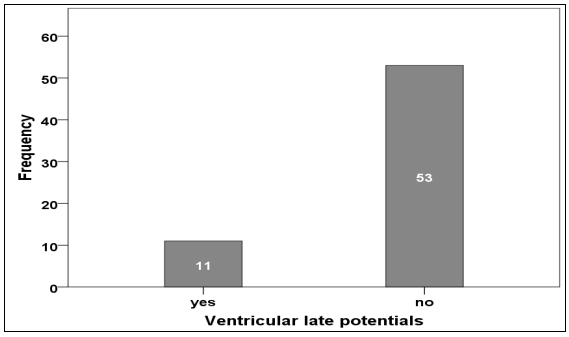

Figure-1: Frequency of ventricular late potentials in patients with systemic arterial hypertension

Descriptive statistics for signal averaged ECG parameters, i.e., filtered QRS complex (fQRS), root mean square (RMS) voltage of the signal in last 20 ms, duration of low amplitude signals (LAS) under 40 μv and the noise level are shown in Table-1.

Table-1: Descriptive statistics of signal averaged ECG parameters (n=64)

Statistical variables	SAECG parameters			
	fQRS (ms)	RMS (μv)	LAS (ms)	Noise (μv)
Mean±SD	108.52±23.63	92.17±51.02	28.81±20.78	0.29±0.25
Median	101.50	100.50	21.00	0.26
Mode	97	30	18	0.00

Correlation was calculated between blood pressure and each variable of signal averaged ECG by using Pearson correlation coefficient as shown in Table-2. Blood pressure was significantly and positively correlated with filtered QRS complex (p=0.001) but not with low amplitude signals or root mean square voltage (p>0.05).

Table-2: Correlation between blood pressure and signal averaged ECG parameters (n=64)

Bivariate correlation	*r*	*p*
Blood pressure and fQRS	0.42	0.001*
Blood pressure and LAS	0.22	0.08
Blood pressure and RMS	0.05	0.69

*significant, fQRS: filtered QRS, LAS: low amplitude signals, RMS: root mean square

DISCUSSION

Results of our study showed that filtered QRS complex had a significant and positive correlation with systemic arterial blood pressure whereas the correlation of low amplitude signals and root mean square voltage with blood pressure was insignificant. This information provides an inkling towards pathogenesis of ventricular arrhythmias in hypertensive patients. Chronic hypertension leads to left ventricular hypertrophy which alters electro-cardiographic properties of the cardiac muscle. Although in this setting all the parameters of the cardiac signal are likely to be affected including duration and voltage, nonetheless, duration seems to be a greater contributor towards arrhythmogenesis. There are high chances that longer duration of filtered QRS

complex will lead to establishment of re-entry circuits resulting in re-entrant ventricular arrhythmias.[7]

Palatini *et al* studied ventricular late potentials in hypertensive patients.[8] One hundred and seven hypertensive patients were enrolled in their study and the frequency of ventricular late potentials was determined through signal averaged ECG. By the use of 40 Hz filter, they found that filtered QRS complex was significantly higher in hypertensive patients (p<0.01) whereas no association was revealed with low amplitude signals and root mean square voltage. The results of Palatini *et al* are similar to our study possibly because the number of cycles averaged were same (400 to 700 cycles) and this had a gross effect on filtered QRS complex. Also, ventricular late potentials were diagnosed on the basis of similar criteria, i.e., filtered QRS complex greater than 114 ms, low amplitude signals under 40 μv greater than 38 ms and root mean square voltage less than 20 μv.

Studies conducted on other diseases had also thrown light on this aspect. Filtered QRS complex among all the three signal averaged ECG parameters was found to be significant in developing ventricular late potentials in different diseases like right ventricular outflow track cardiomyopathy, myocardial infarction and heart failure.[1,2,9] Gadaleta and Giorgio proposed that for time domain analysis, filtered QRS complex had maximum effectiveness (96.7%) among all the signal averaged ECG parameters.[10] In our study, we also found that filtered QRS complex was the most significant component among all the signal averaged ECG parameters in patients with high blood pressure (p=0.001). This implies that perhaps filtered QRS complex has higher contributions than low amplitude signals and root mean square voltage towards the pathogenesis of ventricular late potentials in hypertensive patients. Filtered QRS complex and low amplitude signals are related to duration of the cardiac signal whereas root mean square voltage is related to voltage of the signal. This suggests that electro-physiological modifications pertaining to duration of the cardiac signal are probably involved to a greater extent in generation of ventricular late potentials as compared to the voltage of the signal. This might be due to the changes in calcium and sodium-calcium exchange currents resulting in prolonged action potential duration especially with regards to high blood pressure.[11] This prolonged duration of repolarization may provide an arrhythmogenic substrate upon which early or delayed afterdepolarizations develop and represent as prolonged filtered QRS complex on signal averaged ECG.[12]

Our study revealed reasonably high frequency of ventricular late potentials which were directly correlated with systemic arterial blood pressure. Palmiero *et al* carried out a study to evaluate arrhythmia risk by recording ventricular late potentials in patients with essential hypertension.[13] Their study included 85 patients with systemic arterial blood pressure above 101 mmHg. Seventeen of their patients (20%) had ventricular late potentials on signal averaged ECG. They followed almost the same exclusion criteria as we used in our study. Results of the study conducted by Palmiero *et al* were almost consistent with our study as we found a frequency of 17% in our study population.

Galinier M *et al*[14] studied ventricular late potentials in 214 patients with arterial hypertension.[14] Twenty-seven of their patients (21.6%) had ventricular late potentials which was comparable to the results of our study. Galinier M *et al* recorded signal averaged ECG at a noise level of less than 0.4 μv which was nearer to the noise level of our study. They recruited patients with mean arterial blood pressure of 116 mmHg which was comparable to mean arterial blood pressure of patients enrolled in our study, i.e., 114 mmHg. The exclusion criteria also matched with the criteria that we followed. Similar protocol used in the two studies yielded the comparable results.

Presence of ventricular late potentials in hypertensive patients on signal averaged ECG is considered an evidence of underlying anatomical and electrophysiological changes which can give rise to life threatening ventricular arrhythmias.[5] Hypertension is considered to be a strong independent risk factor for ventricular arrhythmias. Barison *et al*[15] and Aidietis *et al*[16] revealed that patients with systemic arterial hypertension were at increased risk of life threatening ventricular arrhythmias and sudden cardiac death. Detection of such patients through signal averaged ECG is of great clinical importance for their risk stratification and therapy.

CONCLUSION

Patients with higher systemic arterial blood pressure are at greater risk of developing ventricular late potentials which are reflective of ventricular arrhythmias. In hypertensive patients the arrhythmogenesis seems to be more related to duration of the cardiac signal compared to its voltage.

REFERENCES

1. Santangeli P, Pieroni M, Russo AD, Casella M, Pelargonio G, Di Biase L, *et al*. Correlation between signal-averaged ECG and the histologic evaluation of the myocardial substrate in right ventricular outflow tract arrhythmias. Circulation: Arrhythmia and Electrophysiology 2012;5(3):475–83.
2. Matsuzaki A, Yoshioka K, Amino M, Shima M, Hashida T, Fujibayashi D, *et al*. Usefulness of Continuous 24-hour Ventricular Late Potential to Predict Prognosis in Patients with Heart Failure. Tokai J Exp Clin Med 2014;39(3):128–36.
3. Mancia G, Fagard R, Narkiewicz K, Redon J, Zanchetti A, Bohm M, *et al*. ESH/ESC guidelines for the management of arterial hypertension: The Task Force for the Management of Arterial Hypertension of the European Society of Hypertension (ESH) and of the European Society of Cardiology (ESC). Eur Heart J 2013;34(28):2159–219.

4. Hayashi Y, Miyata Y. Preoperative Risk Factors; Hypertension and Arrhythmias. Masui 2015;64(9):902–10.
5. Santangeli P, Infusino F, Sgueglia GA, Sestito A, Lanza GA. Ventricular late potentials: a critical overview and current applications. J Electrocardiol 2008;41(4):318–24.
6. Rudy Y. Noninvasive electrocardiographic imaging of arrhythmogenic substrates in humans. Circ Res 2013;112(5):863–74.
7. Chang MG, de Lange E, Calmettes G, Garfinkel A, Qu Z, Weiss JN. Pro- and anti-arrhythmic effects of ATP-sensitive potassium current activation on re-entry during early afterdepolarization-mediated arrhythmias. Heart Rhythm 2013;10(4):575–82.
8. Palatini P, Maraglino G, Accurso V, Sturaro M, Toniolo G, Dovigo P, *et al*. Impaired left ventricular filling in hypertensive left ventricular hypertrophy as a marker of the presence of an arrhythmogenic substrate. Br Heart J 1995;73(3):258–62.
9. Yodogawa K, Ohara T, Takayama H, Seino Y, Katoh T, Mizuno K. Detection of prior myocardial infarction patients prone to malignant ventricular arrhythmias using wavelet transform analysis. Int Heart J 2011;52(5):286–9.
10. Gadaleta M, Giorgio A. A method for ventricular late potentials detection using time-frequency representation and wavelet denoising. ISRN Cardiol [Internet]. 2012; 2012:[9 p.]. Available from http://www.ncbi.nlm.nih.gov/pmc/ articles/PMC3432549/
11. Wolk R. Arrhythmogenic mechanisms in left ventricular hypertrophy. Europace 2000;2(3):216–23.
12. Yiu K, Tse H. Hypertension and cardiac arrhythmias: a review of the epidemiology, pathophysiology and clinical implications. J Hum Hypertens 2008;22(6):380–8.
13. Palmiero P, Maiello M. Arrhythmic risk in essential hypertension: late potentials. Minerva Cardioangiol 2004;52(1):1–8. [Article in Italian]
14. Galinier M, Balanescu S, Fourcade J, Dorobantu M, Albenque JP, Massabuau P, *et al.* Prognostic value of arrhythmogenic markers in systemic hypertension. Eur Heart J 1997;18(9):1484–91.
15. Barison A, Vergaro G, Pastormerlo LE, Ghiadoni L, Emdin M, Passino C. Markers of arrhythmogenic risk in hypertensive subjects. Curr Pharm Des 2011;17(28):3062–73.
16. Aidietis A, Laucevicius A, Marinskis G. Hypertension and cardiac arrhythmias. Curr Pharm Des 2007;13(25):2545–55.

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