Family Medicine & Primary Care Review 2023; 25(3): 302–309, https://doi.org/10.5114/fmpcr.2023.130092

ORIGINAL PAPERS

ISSN 1734-3402, eISSN 2449-8580

Pattern of platelet indices in hypertension: a single-centre experience for a primary care setting

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A – Study Design, **B** – Data Collection, **C** – Statistical Analysis, **D** – Data Interpretation, **E** – Manuscript Preparation, **F** – Literature Search, **G** – Funds Collection

Summary **Background.** As a neglected piece of cell blood count, platelet indices are readily available in a primary care setting. Current literature aimed at the role of platelet indices in hypertensive disorders is focused mainly on a single platelet index.
Objectives. To better clarify alterations in the pattern of platelet indices in hypertensive disorders, we investigated the relation between a set of platelet indices and hypertensive disorders defined by ambulatory blood pressure monitoring (ABPM).
Material and methods. This cross-sectional study was conducted on 283 patients referred to the Hypertension Clinic of our hospital. ABPM was performed for all cases, and patients were accordingly classified as hypertensive (61.8%) and non-hypertensive (38.2%), as well as dipper (60%) and non-dipper (40%). Blood samples were collected for cell blood count, and ensuing platelet indices were compared between these groups.
Results. The mean level of plateletcrit (PCT) was significantly higher in hypertensive subjects than non-hypertensive individuals (0.235% versus 0.251%, $p = 0.03$). The difference of mean platelet volume (MPV), platelet distribution width (PDW) and platelet large cell ratio (PLCR) was not significant between hypertensive and non-hypertensive cases. The levels of platelet indices were not significantly different between dipper and non-dipper individuals. The mean MPV and PLCR was significantly higher in hypertensive patients with coexisting diabetes mellitus.
Conclusions. We identified a different pattern of platelet indices as "elevated plateletcrit and normal other platelet volume indices" in hypertensive patients. Considering the patterns of alteration in platelet indices, it may be better to describe their role as a biomarker in hypertensive disorders.
Key words: blood pressure monitoring, ambulatory, hypertension, mean platelet volume, biomarkers, diabetes mellitus.

Najafi MT, Fazeli SA, Khatami MR, Abbasi MR, Shojamoradi MH. Pattern of platelet indices in hypertension: a single-centre experience for a primary care setting. *Fam Med Prim Care Rev* 2023; 25(3): 302–309, doi: https://doi.org/10.5114/fmpcr.2023.130092.

Background

Hypertensive disorder is the leading cause of death all over the world [1]. The role of platelet in the pathogenesis, progression and complications of hypertensive disorders remains to be elucidated more comprehensively. Several alterations have been described in platelets derived from hypertensive subjects, including elevated aggregation tendency, more release of β-thromboglobulin and P-selectin, lower nitric oxide (NO) production and increased intraplatelet calcium level [2, 3]. These changes represent more activation of platelets and could lead to a change in platelet morphology from discoid to spherical shape [4]. Whether these alterations are the cause or consequence of elevated blood pressure is still unclear.

Platelet indices are neglected piece of cell blood count which are readily available in a primary care setting. These indices are related to the kinetic and morphology of platelets and reflect the degree of platelet activation. In the physiologic point of view, the platelet indices could roughly be categorised into two groups: those which are more significant for platelet production, such as platelet count and plateletcrit (PCT), and indices which are more related to platelet activity, like mean platelet volume (MPV), platelet distribution width (PDW) and platelet with a large cell ratio (PLCR) [5].

An accumulating bulk of evidence has been documentied in recent years suggesting platelet indices as potential diagnostic and prognostic biomarkers in different disciplines of medicine, including malignancies, inflammatory disorders and cardiovascular diseases [5, 6]. In the field of hypertension, ongoing studies have shown alterations of platelet indices in different hypertensive disorders such as pregnancy-induced hypertension, essential hypertension, resistant hypertension and abnormal night-time blood pressure dipping [7–10].

Most current literature on the role of platelet indices in hypertensive disorders is focused mainly on a single platelet index. For example, in the study of Pusuroglu et al., MPV was the only index which was evaluated in the non-dipping pattern of blood pressure [9], and Li et al. merely assessed the role of PDW in hypertensive subjects [11]. Consequently, a viewpoint considering all the indices together as a distinct pattern of platelet status in hypertensive disorders is lacking. Furthermore, the results of studies evaluating platelet indices in hypertension are inconsistent and controversial.

Objectives

To better clarify the alterations in the pattern of platelet indices in hypertensive disorders, we investigate the relation between a set of platelet indices derived from cell blood count with hypertension as well as night-time blood pressure dipping defined by ambulatory blood pressure monitoring (ABPM).

Material and methods

Study population

This cross-sectional study was done at our centre from September 2019 to July 2020. The study included all consecutive non-smoking subjects who referred to the Hypertension Clinic of our hospital if they were older than 18 years of age and signed the written informed consent. Patients with any following criteria were excluded: pregnancy, confirmed history of chronic medical illnesses, including kidney failure or liver dysfunction, history of malignancy or haematologic abnormalities affecting platelets, acute coronary syndrome and stroke.

Ethical issues

The study protocol was in accordance with Declaration of Helsinki and approved by our local ethical committee. All subjects signed the written informed consent. Ethical approval code: IR.TUMS.IKHC.REC.1398.053.

BP monitoring

ABPM was performed by the oscillometric method using Microlife WatchBP O3 (Microlife AG, Windau, Switzerland) with an appropriately sized cuff placed on the non-dominant hand. The device was programmed to record BP every 30 minutes in the waking period and every 60 minutes during sleep, according to patients' reports of their usual daily schedule. The ABPM was accepted if more than 70% of measurements were successful.

Blood sampling

Following overnight fasting, blood samples were collected through careful puncture of the cubital vein into standardised tubes containing EDTA for anticoagulation. The samples were analysed within 2 hours by an automated blood cell counter (Sysmex XT-1800i, Kobe, Japan) for complete blood count.

Study variables

The following platelet volume indices evaluated in this study:
MPV: mean platelet volume as fL.
PLCR: platelet large cell ratio (percentage of platelets larger than 12 fL).
PDW: platelet distribution width.
PCT (plateletcrit): the percentage of blood volume occupied by platelets.
The values of MPV, PLCR and PDW retrieved from autoanalyzer, and PCT was calculated as a product of MPV and platelet count. Based on ABPM data, hypertension was defined according to the 2018 ESC/ESH Clinical Practice Guidelines for the Management of Arterial Hypertension. Compared to day-time BP, normal dipping was defined as a 10% to 20% decrease in night-time BP [12]. The patients were considered "hypertensive" if they met the ABPM criteria at the time of study.

Statistical analysis

Statistical analysis was done by SPSS version 13 for Windows (SPSS Inc., IL, USA). Continuous variables were expressed by means and standard deviation and categorical variables as number and percentage. The Independent Sample *t*-Test was used to show the differences in continuous variables with normal distribution, and the Mann-Whitney U-test if skewed. Chi-squared analysis was applied to compare the differences in categorical variables. The relation between continuous variables was assessed by Pearson correlation coefficient. A *p*-value of less than 0.05 was considered significant.

Results

Baseline characteristics

During the study period, 283 cases were included. The mean age of subjects was 52.8 years, and 72.8% were female. About 15% (43 cases) had diabetes mellitus. The average amount of 24-hour systolic and diastolic blood pressure was 124.84 mm Hg and 76.4 mm Hg, respectively. Considering ABPM data, 61.8% of study population (175 cases) was hypertensive; 32.5% with day-time and 60.1% with night-time hypertension. Abnormal BP dipping was recorded in about 40% of our patients. Excepting day-time diastolic BP, other BP measurements were significantly greater in non-dipper cases, and these patients were more likely to be hypertensive than normal dippers (77.9% versus 51.2%, $p < 0.005$).

ABPM data and platelet volume indices

According to hypertension status and the dipping pattern of BP, Table 1 compares demographic data, ABPM parameters and platelet volume indices in the study population. The average amount of PCT in hypertensive subjects was significantly greater than non-hypertensive individuals (0.23% versus 0.25%, $p = 0.03$). The difference of MPV, PDW and PLCR was not significant between hypertensive and non-hypertensive cases. As illustrated in Table 2, no significant correlation was found between blood pressure measurements by ABPM and indices of platelet volume.

Table 1. Comparing demographic data, ABPM parameters and platelet volume indices according to hypertension status and dipping pattern of blood pressure

	Total	Hypertension status			Dipping pattern		
		Non-hypertensive (*n* = 108)	Hypertensive (*n* = 175)	*p*	Dipper (*n* = 170)	Non-dipper (*n* = 113)	*p*
General description							
Gender							
Male *n* (%) Female *n* (%)	77 (27.2) 206 (72.8)	27 (35.1) 81 (39.3)	50 (64.9) 125 (60.7)	0.5	42 (54.6) 128 (62.1)	35 (45.4) 78 (37.9)	0.37
Age (yr)	52.80 ± 14.00	54.02 ± 15.3	52.05 ± 13.07	0.25	53.05 ± 13.5	53.1 ± 14.3	0.98
eGFR (ml/min/1.73 m^2)	73.94 ± 20.61	71.4 ± 21.3	75.5 ± 20	0.1	72.91 ± 20.7	73.8 ± 19.1	0.73
BMI (kg/m^2)	28.94 ± 4.90	29.22 ± 5	28.77 ± 4.8	0.46	29.12 ± 4.7	28.99 ± 5.2	0.85
Diabetes mellitus *n* (%)	43 (15.2)	15 (34.9)	28 (65.1)	0.6	27 (62.8)	16 (37.2)	0.75

Table 1. Comparing demographic data, ABPM parameters and platelet volume indices according to hypertension status and dipping pattern of blood pressure (continued)

	Total	Hypertension status			Dipping pattern		
		Non-hypertensive (*n* = 108)	Hypertensive (*n* = 175)	*p*	Dipper (*n* = 170)	Non-dipper (*n* = 113)	*p*
24-hr ABPM parameters							
24-hr systolic BP (mm Hg)	124.84 ± 14.43	113.22 ± 7.7	132.01 ± 12.8	< 0.005	123.17 ± 12.6	128.71 ± 16.6	0.008
24-hr diastolic BP (mm Hg)	76.40 ± 10.40	67.93 ± 4.8	81.63 ± 9.4	< 0.005	75.24 ± 9	78.78 ± 12.6	0.02
Awake systolic BP (mm Hg)	126.98 ± 14.64	116.1 ± 8.4	133.69 ± 13.6	< 0.005	126.23 ± 12.8	130.19 ± 17	0.04
Awake diastolic BP (mm Hg)	78.36 ± 10.53	70.37 ± 5.6	83.29 ± 9.8	< 0.005	77.71 ± 9.2	80.34 ± 12.7	0.07
Asleep systolic BP (mm Hg)	119.44 ± 16.07	106.12 ± 8.5	127.66 ± 14	< 0.005	115.5 ± 13.5	124.94 ± 18.4	< 0.005
Asleep diastolic BP (mm Hg)	71.60 ± 11.47	62.02 ± 4.9	77.51 ± 10.2	< 0.005	69.38 ± 9.2	74.75 ± 13.9	0.001
Pulse pressure (mm Hg)	48.43 ± 8.65	45.29 ± 6.1	50.37 ± 9.3	< 0.005	47.92 ± 8.5	49.93 ± 9	0.09
MAP (mm Hg)	92.54 ± 11.18	83 ± 5.22	98.42 ± 9.7	< 0.005	91.21 ± 9.5	95.41 ± 13.4	0.01
Hypertension status							
24-hr hypertension *n* (%)	175 (61.8)	–	–	–	87 (49.8)	88 (50.2)	< 0.005
Day-time hypertension *n* (%)	92 (32.5)	–	–	–	45 (49)	47 (51)	0.01
Night-time hypertension *n* (%)	170 (60.1)	–	–	–	85 (50)	85 (50)	< 0.005
Patterns of dipping							
Normal dipping *n* (%)	170 (59.9)	83 (48.8)	87 (51.2)	< 0.005	–	–	–
Abnormal dipping *n* (%)	113 (40.1)	25 (22.1)	88 (77.9)		–	–	–
Haematologic parameters							
MPV (fL)	9.81 ± 1.1	9.74 ± 1.16	9.85 ± 1.07	0.41	9.81 ± 1	9.79 ± 1.1	0.9
PDW	14.36 ± 2.29	14.27 ± 2.3	14.41 ± 2.2	0.62	14.3 ± 2.1	14.76 ± 2.2	0.12
PLCR	30.36 ± 9.49	29.12 ± 8.5	31.11 ± 9.9	0.08	30.18 ± 9.1	31.29 ± 9.1	0.37
Platelet count (*10^9/L)	247.46 ± 69.42	243.56 ± 58	255.98 ± 66	0.1	250.06 ± 64	252.41 ± 64	0.79
PCT	0.244 ± 0.06	0.235 ± 0.05	0.251 ± 0.06	0.03	0.245 ± 0.06	0.243 ± 0.06	0.8

Independent Sample *t*-Test used to show the differences in variables with normal distribution, and Mann-Whitney U-test if skewed. The difference in categorical variables was compared by Chi-squared analysis. ABPM – Ambulatory Blood Pressure Monitoring; eGFR – estimated Glomerular Filtration Rate based on CKD-EPI formula; BMI – Body Mass Index; MAP – Mean Arterial Pressure; MPV – Mean Platelet Volume; PDW – Platelet Distribution Width; PLCR – Platelet Large Cell Ratio; PCT – Plateletcrit.

Table 2. Correlation between ABPM parameters and platelet volume indices. *R* represents Pearson correlation coefficient, and *p* denotes its significance

	Mean 24-hr SBP (mm Hg)	Mean 24-hr DBP (mm Hg)	Mean awake SBP (mm Hg)	Mean awake DBP (mm Hg)	Mean asleep SBP (mm Hg)	Mean asleep DBP (mm Hg)
Platelet count (*10^9/L)	*R* = 0.009 *p* = 0.87	*R* = 0.052 *p* = 0.38	*R* = 0.004 *p* = 0.94	*R* = 0.050 *p* = 0.4	*R* = 0.012 *p* = 0.845	*R* = 0.042 *p* = 0.48
MPV (fL)	*R* = 0.058 *p* = 0.33	*R* = 0.04 *p* = 0.5	*R* = 0.052 *p* = 0.38	*R* = 0.032 *p* = 0.59	*R* = 0.07 *p* = 0.23	*R* = 0.061 *p* = 0.31
PDW	*R* = 0.033 *p* = 0.58	*R* = -0.012 *p* = 0.84	*R* = 0.025 *p* = 0.67	*R* = -0.020 *p* = 0.74	*R* = 0.055 *p* = 0.35	*R* = 0.015 *p* = 0.8
PLCR	*R* = 0.07 *p* = 0.24	*R* = 0.037 *p* = 0.54	*R* = 0.057 *p* = 0.34	*R* = 0.019 *p* = 0.75	*R* = 0.1 *p* = 0.089	*R* = 0.085 *p* = 0.15
PCT	*R* = 0.027 *p* = 0.64	*R* = 0.055 *p* = 0.64	*R* = 0.021 *p* = 0.72	*R* = 0.053 *p* = 0.37	*R* = 0.034 *p* = 0.57	*R* = 0.048 *p* = 0.42

ABPM – Ambulatory Blood Pressure Monitoring; SBP – Systolic Blood Pressure; DBP – Diastolic Blood Pressure: MPV – Mean Platelet Volume; fL – Femtoliter; PDW – Platelet Distribution Width; PLCR – Platelet Large Cell Ratio; PCT – Plateletcrit.

Dipping pattern and platelet volume indices

The mean level of MPV in dippers and those with abnormal dipping was 9.81 fL versus 9.79 fL with no statistical significance ($p = 0.9$). The difference of PDW, PLCR and PCT was not significant between dipper and non-dipper individuals (Table 1). A subgroup analysis also did not show a significant difference in platelet volume indices between dippers and non-dippers in both hypertensive and non-hypertensive cases (Figure 1).

Diabetes mellitus and platelet volume indices

As shown in Table 3, the average amount of MPV was significantly higher in diabetic patients than non-diabetic individuals (10.2 ± 1.14 versus 9.74 ± 1.08 fL, $p = 0.011$). PLCR was also significantly greater in diabetics. Subgroup analyses showed similar findings in hypertensive diabetic patients. In non-hypertensive cases, the difference between MPV and PLCR was not significant in diabetic and non-diabetic cases. The difference of PDW and PCT was not significant between diabetic and non-diabetic individuals. This was true for both hypertensive and non-hypertensive cases.

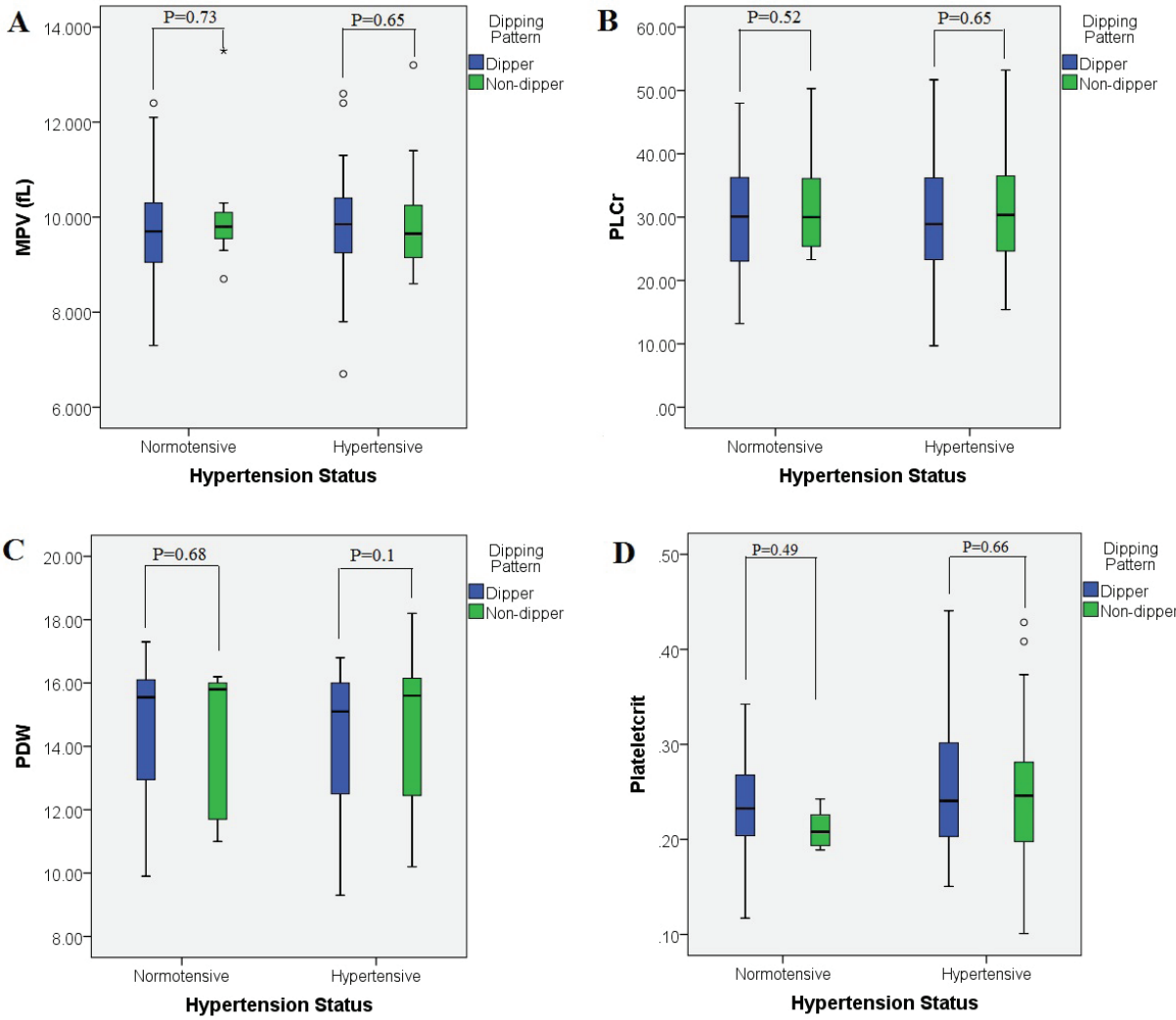

Figure 1. Comparing MPV (A), PLCR (B), PDW (C) and plateletcrit between dippers and non-dippers according to hypertension status

Independent Sample *t*-Test and Mann-Whitney U-test were used to show the differences in variables with normal distribution and skewed variables, respectively. MPV – Mean Platelet Volume; PDW – Platelet Distribution Width; PLCR – Platelet Large Cell Ratio.

Table 3. Platelet volume indices in diabetic and non-diabetic subjects

	Diabetes mellitus			Hypertension status					
				Hypertensive *n* = 175			Non-hypertensive *n* = 108		
	Diabetic *n* = 43	Non-diabetic *n* = 240	*p*	Diabetic *n* = 28	Non-diabetic *n* = 147	*p*	Diabetic *n* = 15	Non-diabetic *n* = 93	*p*
MPV (fL)	10.2 ± 1.14	9.74 ± 1.08	0.011	10.33 ± 1.11	9.76 ± 1.04	0.009	9.96 ± 1.2	9.71 ± 1.15	0.43
PDW	14.57 ± 2.1	14.32 ± 2.32	0.5	14.89 ± 1.95	14.32 ± 2.34	0.23	14 ± 2.29	14.31 ± 2.32	0.63
PLCR	33.46 ± 10.33	29.8 ± 9.24	0.02	35.33 ± 10.47	30.31 ± 9.68	0.014	29.96 ± 9.43	28.98 ± 8.48	0.68
Platelet count (*10^9/L)	239.88 ± 53.73	253.22 ± 65.64	0.21	246.64 ± 57.78	257.82 ± 68.66	0.42	227.27 ± 44.26	246.19 ± 60.44	0.24
PCT	0.245 ± 0.06	0.244 ± 0.06	0.95	0.255 ± 0.06	0.250 ± 0.06	0.71	0.227 ± 0.05	0.236 ± 0.05	0.53

Independent Sample *t*-Test used to show the differences in variables with normal distribution, and Mann-Whitney U-test if skewed. MPV – Mean Platelet Volume; PDW – Platelet Distribution Width; PLCR – Platelet Large Cell Ratio; PCT – Plateletcrit.

Antihypertensive medications and platelet volume indices

Figure 2 shows the distribution of antihypertensive medication in the study population. As illustrated, ACE inhibitors and angiotensin receptor blockers were the most frequent antihypertensive medications followed by calcium channel blockers, beta blockers and diuretics. Compared to those not receiving antihypertensive drugs, the average amount of platelet indices was not different in patients who were on such medications (Table 4).

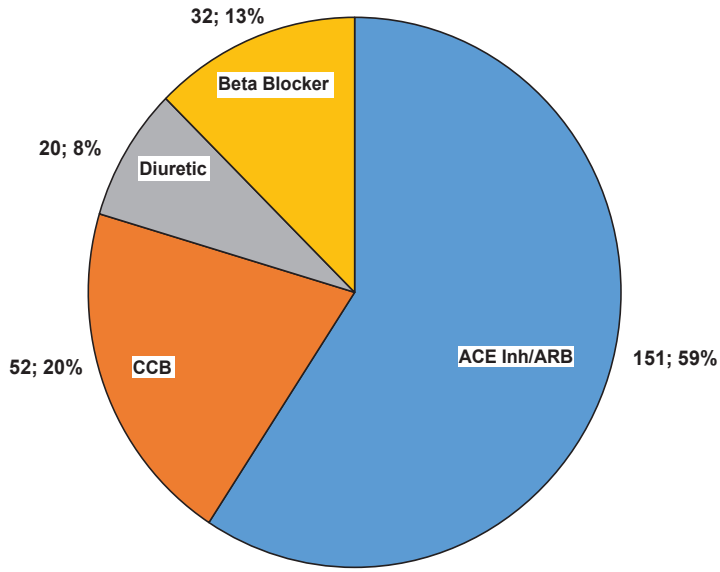

Figure 2. Distribution of antihypertensive medication in the study population. ACE inhibitors and angiotensin receptor blockers were the most antihypertensive medications followed by calcium channel blockers, beta blockers and diuretics

Table 4. Comparing ABPM data, dipping pattern and platelet indices in those who were and were not receiving antihypertensive medication

	Antihypertensive medications		
	Yes	No	*p*
24-hr ABPM parameters			
24-hr systolic BP (mm Hg)	126.02 ± 14.52	123.05 ± 14.27	0.09
24-hr diastolic BP (mm Hg)	77.75 ± 10.77	74.17 ± 9.51	0.005
Awake systolic BP (mm Hg)	127.86 ± 14.53	125.67 ± 14.88	0.22
Awake diastolic BP (mm Hg)	79.5 ± 10.82	76.47 ± 9.9	0.019
Asleep systolic BP (mm Hg)	121.35 ± 16.91	116.44 ± 14.34	0.013
Asleep diastolic BP (mm Hg)	73.34 ± 12.26	68.74 ± 6.55	0.001
Patterns of dipping			
Normal dipping (%) Abnormal dipping (%)	63.6% 59.1%	36.4% 40.9%	0.29
Platelet indices			
MPV (fL)	9.79 ± 1.16	9.87 ± 1.07	0.55
PDW	14.39 ± 2.27	14.27 ± 2.34	0.69
PLCR	30.28 ± 9.5	30.34 ± 9.46	0.95
Platelet count (*10^9/L)	253.23 ± 67.07	249.59 ± 58.15	0.64
PCT	0.245 ± 0.06	0.246 ± 0.06	0.9

Independent Sample *t*-Test used to show the differences in variables with normal distribution, and Mann-Whitney U-test if skewed. The difference in categorical variables was compared by Chi-squared analysis. ABPM – Ambulatory Blood Pressure Monitoring; MPV – Mean Platelet Volume; PDW – Platelet Distribution Width; PLCR – Platelet Large Cell Ratio; PCT – Plateletcrit.

Table 5. Different patterns of platelet indices in hypertensive disorders

Study	Hypertensive disorder	MPV	PDW	PLCR	Platelet count	PCT	Findings
Yang K. et al. 2016 [10]	Elevated blood pressure	↑↓	↓	Not included	↑	Not included	Negative association of MPV with SBP in males and positive association with DBP in females. Negative association of PDW and SBP. Association of platelet count and DBP in males.
Ates I. et al. 2015 [28]	Proteinuria associated with hypertension	↑	↑	Not included	↑	↑	Higher levels of platelet count, plateletcrit, MPV and PDW in hypertensives with proteinuria.
Cetin N. et al. 2019 [19]	Non-dipping status in paediatric hypertensives	↑	Not included	↔	↑	↔	Association between non-dipper status and MPV with platelet count.

Table 5. Different patterns of platelet indices in hypertensive disorders (continued)

Study	Hypertensive disorder	MPV	PDW	PLCR	Platelet count	PCT	Findings
Bawore SG. et al. 2022 [7]	Preeclampsia	↑	↑	Not included	↓	↓	Positive relationship of MPV and PDW with MAP. Decrease in platelet count and PCT with increasing severity of preeclampsia.
Current study, 2022	Dipping status and elevated blood pressure	↔	↔	↔	↔	↑	Elevated PCT in hypertensives.

MPV – Mean Platelet Volume; PDW – Platelet Distribution Width; PLCR – Platelet Large Cell Ratio; PCT – Plateletcrit; SBP – Systolic Blood Pressure; DBP – Diastolic Blood Pressure; MAP – Mean Arterial Pressure; ↑ – positive association; ↓ – negative association; ↔ – no association.

Discussion

Platelet is a ubiquitous cell with a diverse haemostatic and non-haemostatic function representing this cell as a key component in many cardiovascular diseases [13]. The novel perspective of platelet indices as a "biomarker" which is capable of tracing and following-up platelet status has opened a new venue for daily clinical practice, particularly in primary care settings [5]. In this study, we found that PCT was significantly higher in hypertensive subjects, but according to hypertension status and night-time blood pressure dipping, other platelet indices volume did not differ in the study population.

Several studies evaluated the relationship between a single platelet volume index and ABPM parameters, but the data in this regard is conflicting. MPV represents a simple marker of platelet activation and shows the susceptibility of platelets to aggregation. Li et al. found no association between MPV and hypertension subtypes [14]. In a study by Pusuroglu et al., MPV was significantly higher in hypertensive patients than normotensive subjects. Similar to our findings, the authors observed no significant difference in MPV between dipper and non-dipper hypertensive subjects [9]. In contrast, an inverse correlation of MPV with a nocturnal drop of systolic BP in prehypertensive patients was reported by Sadeghi et al. [15]. Alpsoy et al. determined a cut-off value of 9.1 fL for MPV to detect the reverse dipping pattern of BP with a sensitivity and specificity of 60% and 69%, respectively [16].

Platelet distribution width was used for evaluation of heterogeneity in the volume of platelets. Li et al. showed that the prevalence of isolated systolic hypertension in females raised by increasing PDW quartile, but such association in males was insignificant. Furthermore, no significant association was found between PDW and other types of hypertension [11].

Plateletcrit is the total mass of platelet in blood and represents the equilibrium between platelet regeneration and elimination [17]. We found a significantly higher PCT in hypertensive patients than non-hypertensive individuals. Limited studies had been conducted assessing the association between PCT and hypertensive disorders. In a retrospective study with a limited sample size, Shanker et al. concluded that PCT might be an important indicator of organ damage induced by hypertension [18]. In that study, hypertension was defined by office blood pressure readings and other haematologic parameters, including mean corpuscular volume (MCV), which was also significantly higher in hypertensive subjects. This finding has not been proven by other studies. Other studies evaluated PCT in preeclampsia [7] and paediatric patients with hypertension [19]. Hence, to the best of our of knowledge, the current study is one of the first surveys which evaluates the association of PCT and ABPM parameters in adult non-pregnant individuals.

In contrast, to consider any platelet index as an individual marker, a new composite framework developing a profile of all platelet indices together can prepare multiple phenotypes reflecting patients' platelet status in daily practice. The current study revealed a novel pattern of platelet indices in hypertensive patient as "elevated PCT and normal other platelet volume indices". A review of literature showed that multiple patterns of platelet indices have been described up to now, which were summarised in Table 5.

The clinical significance and underlying mechanisms of such variable patterns of platelet indices have not been clearly explained. However, it can be proposed that there may be multiple different platelet phenotypes based on population type, type of the underlying disease and even different stages of one disease in patients. For example, Cetin and Tufan showed that MPV and platelet count, but not PCT, were independently associated with non-dipping status in paediatric patients with hypertension [19]. In a study by Bawore et al., while higher levels of platelet volume indices including MPV and PDW were reported in patients with preeclampsia, platelet count and PCT were significantly lower in such patients [7].

Several studies evaluated the role of platelet indices as available biomarkers in various aspects of diabetes mellitus, like glycaemic control and its micro- and macrovascular complications [20–23]. In this study, we evaluated the combined interactions of hypertension and diabetes mellitus on platelet volume indices. According to our result, diabetes mellitus would have a distinct pattern of platelet indices with only elevated MPV and PLCR. Interestingly, diabetic hypertensives tend to have a platelet pattern which is more similar to the pattern found in our diabetic patients. This could be suggestive for prominent effects of diabetes on platelet indices in the case of coexisting diabetes mellitus and hypertension.

Our findings failed to show any relationship between various types of antihypertensive medications and platelet indices. Studies evaluating the interaction of antihypertensive drugs and platelet indices are conflicting. For example, the study by Demirtunc et al. revealed no effect of amlodipine on MPV [24]. Conversely, Nadar et al. showed a reversal of abnormal platelet morphology following treatment with amlodipine-based antihypertensive therapy [25]. Further studies are required to better specify the role of different classes of antihypertensive medications on platelet indices in hypertensive disorders.

We encountered some limitations in this research. First, although we tried to apply a standard method for blood sampling and laboratory analysis, we did not consider all the potential factors which might influence the platelet indices. For example, we considered antihypertensive drugs, but data about other medications, like antiplatelet agents, used by our patients were the missing piece of puzzle. Second, we used ABPM to define hypertensive disorders in the study population, and the use of antihypertensive medications was not considered as one of the criteria for the diagnosis of hypertension. As a result, there might be some cases of controlled hypertension which were included in the non-hypertensive group of our cases. Finally, although several guidelines consider ABPM as the best method for diagnosis of hypertension, lack of reproducibility remains an obstacle which needs to be overcome by increasing the time of blood pressure monitoring to 48 hours [26, 27]. As with similar studies, the time of blood pressure monitoring in our study was 24 hours.

Conclusions

In this research, we evaluated the relationship between a set of platelet indices and ABPM parameters and identified a different pattern of altered platelet indices as "elevated PCT and normal other platelet volume indices" in hypertensive patients. Consideration of the patterns of alteration in platelet indices, rather than a single platelet index, may better describes the role of such valuable and inexpensive indices as a biomarker in hypertensive disorders. Further studies are mandatory to better clarify the clinical significance and underlying mechanisms of different patterns of platelet indices in hypertension.

Acknowledgement. This article is part of thesis by Seyed Amirhossein Fazeli for a post-graduate degree in nephrology and was supported by Tehran University of Medical Sciences (Grant No 98-01-146-41931). The authors appreciate the nursing staff of the Hypertension Clinic of the Imam Khomeini Hospital complex, especially Mrs. Parvaram and Mrs. Tehrani, for their kind cooperation.

Source of funding: This work was funded from the authors' own resources.
Conflicts of interest: The authors declare no conflicts of interest.

References

1. Lim SS, Vos T, Flaxman AD, et al. A comparative risk assessment of burden of disease and injury attributable to 67 risk factors and risk factor clusters in 21 regions, 1990–2010: a systematic analysis for the Global Burden of Disease Study 2010. *Lancet* 2012; 380(9859): 2224–2260.
2. Blann A, Lip G, Islim I, et al. Evidence of platelet activation in hypertension. *J Hum Hypertens* 1997; 11(9): 607–609.
3. Camilletti A, Moretti N, Giacchetti G, et al. Decreased nitric oxide levels and increased calcium content in platelets of hypertensive patients. *Am J Hypertens* 2001; 14(4 Pt 1): 382–386.
4. Park Y, Schoene N, Harris W. Mean platelet volume as an indicator of platelet activation: methodological issues. *Platelets* 2002; 13(5–6): 301–306.
5. Pogorzelska K, Krętowska A, Krawczuk-Rybak M, et al. Characteristics of platelet indices and their prognostic significance in selected medical condition – a systematic review. *Adv Med Sci* 2020; 65(2): 310–315.
6. Korniluk A, Koper-Lenkiewicz OM, Kamińska J, et al. Mean platelet volume (MPV): new perspectives for an old marker in the course and prognosis of inflammatory conditions. *Mediators Inflamm* 2019; 2019: 9213074.
7. Bawore SG, Adissu W, Niguse B, et al. A pattern of platelet indices as a potential marker for prediction of pre-eclampsia among pregnant women attending a Tertiary Hospital, Ethiopia: A case-control study. *PLoS ONE* 2021; 16(11): e0259543.
8. Surgit O, Pusuroglu H, Erturk M, et al. Assessment of mean platelet volume in patients with resistant hypertension, controlled hypertension and normotensives. *Eurasian J Med* 2015; 47(2): 79–84.
9. Pusuroglu H, Cakmak HA, Erturk M, et al. Assessment of the relation between mean platelet volume, non-dipping blood pressure pattern, and left ventricular mass index in sustained hypertension. *Med Sci Monit* 2014; 20: 2020–2026.
10. Yang K, Tao L, Mahara G, et al. An association of platelet indices with blood pressure in Beijing adults: Applying quadratic inference function for a longitudinal study. *Medicine* (Baltimore) 2016; 95(39): e4964.
11. Li T, Jin J, Meng Z, et al. The different associations between platelet distribution width and hypertension subtypes in males and females. *Biosci Rep* 2020; 40(11): BSR20201747.
12. Vidal-Petiot E, Elbez Y, Lüscher TF, et al. The 2018 ESC-ESH guidelines for the management of arterial hypertension leave clinicians facing a dilemma in half of the patients. *Eur Heart J* 2018; 39(45): 4040–4041.
13. Blann AD, Nadar S, Lip GY. Pharmacological modulation of platelet function in hypertension. *Hypertension* 2003; 42(1): 1–7.
14. Li T, Meng Z, Zhang W, et al. No obvious association exists between mean platelet volume and hypertension subtypes. *Biomark Med* 2021; 15(8): 577–584.
15. Sadeghi MT, Soroureddin Z, Nouri-Vaskeh M, et al. Association of the mean platelet volume and red cell distribution width with dipper and non-dipper blood pressure in prehypertensive non-smokers. *BMC Res Notes* 2019; 12(1): 824.
16. Alpsoy Ş, Gökçek S, Özkaramanlı Gür D, et al. The relationship between mean platelet volume and reverse dipping blood pressure pattern in patients with essential hypertension. *Clin Exp Hypertens* 2021; 43(7): 671–676.
17. Wiwanitkit V. Plateletcrit, mean platelet volume, platelet distribution width: its expected values and correlation with parallel red blood cell parameters. *Clin Appl Thromb Hemost* 2004; 10(2): 175–178.
18. Shanker S, Niranjana Murthy B. Plateletcrit – An important indicator of hypertension induced organ damage. *RJ MAHS* 2020; 3(2): doi: 10.46319/RJMAHS.2020.v03i02.001.
19. Cetin N, Tufan AK. Platelet activation and inflammation in hypertensive children with non-dipper and dipper status. *Iran J Kidney Dis* 2019; 13(2): 105–112.
20. Buch A, Kaur S, Nair R, et al. Platelet volume indices as predictive biomarkers for diabetic complications in type 2 diabetic patients. *J Lab Physicians* 2017; 9(2): 84–88.
21. Waghale RM, Khot RS, Joshi PP. Platelet volume indices: markers of carotid atherosclerosis in type 2 diabetes mellitus? *Clinical Diabetology* 2020; 9(2): 103–111.
22. Ji S, Zhang J, Fan X, et al. The relationship between mean platelet volume and diabetic retinopathy: a systematic review and meta-analysis. *Diabetol Metab Syndr* 2019; 11: 25.
23. Chawla R, Sahu J, Punyani H, et al. Evaluation of platelet volume indices as predictive biomarkers of microvascular complications in patients with type 2 diabetes. *Int J Diabetes Dev Ctries* 2021; 41(1): 89–93.
24. Demirtunc R, Duman D, Basar M. Effects of doxazosin and amlodipine on mean platelet volume and serum serotonin level in patients with metabolic syndrome. *Clin Drug Investig* 2007; 27(6): 435–441.
25. Nadar S, Blann A, Lip G. Platelet morphology and plasma indices of platelet activation in essential hypertension: effects of amlodipine-based antihypertensive therapy. *Ann Med* 2004; 36(7): 552–557.
26. Stergiou GS, Palatini P, Parati G, et al. 2021 European Society of Hypertension practice guidelines for office and out-of-office blood pressure measurement. *J Hypertens* 2021; 39(7): 1293–1302.
27. Steen M, van der, Lenders J, Graafsma S, et al. Reproducibility of ambulatory blood pressure monitoring in daily practice. *J Hum Hypertens* 1999; 13(5): 303–308.
28. Ates I, Bulut M, Ozkayar N, et al. Association between high platelet indices and proteinuria in patients with hypertension. *Ann Lab Med* 2015; 35(6): 630–634.

Tables: 5
Figures: 2
References: 28

Received: 17.03.2022
Reviewed: 06.07.2022
Accepted: 19.01.2023

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