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Original Article

Hematologic disorders during essential hypertension

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ABSTRACT

Background: Besides the traditional risk factors, hematological changes may be involved in the development of arterial hypertension and in its pathogenesis.
Methods: The study, conducted on a sample of 545 subjects, 215 with hypertension and 330 witnesses, were evaluated for peripheral blood parameters in western Algeria; Logistic regression analysis was used to predict hypertension with hematological parameters.
Results: The characters studied related significantly; lower red blood cell levels have a three-and-a-half-fold risk of developing hypertension compared to those who have normal red blood cell counts (OR = 3.64, 95% CI = 1.37–9.65, $p < 0.05$). Subjects who have mean corpuscular volume rate below 80 fl are more exposed to hypertension (OR = 13.58, 95% CI = 4.68–39.41, p = 0.000). The mean corpuscular hemoglobin concentration reveals that subjects who have a lower than normal (<27 pg) are once less exposed to hypertension (OR = 0.04, 95% CI = 0.01–0.13, p = 0.000). Subjects who have lower platelet count than normal are twelve times more exposed to hypertension (OR = 12.13, 95% CI = 1.45–101.18, P = 0.021). Finally, the increase in sedimentation rate at one hour increases the risk of hypertension by 56.63 times compared to subjects with normal sedimentation rate (OR = 56.63, 95% CI = 3.37–597.33, P = 0.001).
Conclusions: Hematological profile associated with essential hypertension retained Red blood cells ratio, mean corpuscular volume, mean corpuscular hemoglobin concentration, platelet ratio, and sedimentation rate at one hour.

1. Introduction

Hypertension, also known as high blood pressure, is a global public health issue. It contributes to the burden of heart disease, stroke and kidney failure and premature mortality and disability [1]. The adverse health consequences of hypertension are compounded because many affected people also have other health risk factors who include tobacco use, obesity, high cholesterol and diabetes mellitus [2].

Besides these traditional factors, there is a number of disputes in various studies with respect to variability of hematological parameters in patients with hypertension and normotensive subjects. Impaired hematological parameters may strongly indicate hypertensive end-organ damage, specifically kidney failure [3–5]. Specifically increased Hgb level may cause left ventricular hypertrophy while low Hgb levels causes anemia and heart failure [6].

The prognostic situation of the hypertension is closely related to the modification of hematological parameters. To our knowledge, few data are available in the literature. In this regard, the prediction and identification of hypertension takes up a large share in the clinical practice.

In accordance with this idea, Logistic regression analysis was used to investigate the relationships between hematological parameters and hypertension.

2. Methods

Epidemiologic, multicentric, case-control study of the pathogenesis of Primary or essential hypertension was conducted in western Algeria, between September 1st, 2017 and January 31st, 2018.

Hypertensive patients (215) were invited to participate in this study when they met the following criteria: previously diagnosed with hypertension (at least three measures of systolic blood

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pressure ≥140 mm Hg and diastolic blood pressure ≥90 mm Hg) , known and treated for hypertension for at least 1 year, and aged ≥ 50 years. 330 normotensive controls were randomly selected, matched by age and gender. The controls had to meet the following criteria: never diagnosed with hypertension, not receiving antihypertensive treatment and systolic blood pressure <140 mm Hg and diastolic blood pressure <90 mm Hg when measured at two consultations the time of health examination.

Baseline characteristics of the study population were assessed by means of interviews with structured questionnaires. Biological samples with folloing data also are collected from the patients: Red blood cell count, Hemoglobin level, Hematocrit, MCV, MCH, and MCHC.

The blood parameters were analyzed using by Automated Hematology Analyzer Beckmon Coulter 750 using impedance method.

The clinical part of this study was conducted in accordance with the Declaration of Helsinki and Guidelines for Good Clinical Practice.

The study was approved by the Ethical Committee of Mascara public Hospital, Saida public Hospital ans Ethical Committee of Tlemcen University Central Hospital. All subjects gave signed informed consent before any study related activities.

3. Statistical analysis

Analysis of data was performed using Minitab 16 for Windows (for multivariate pattern analyses.). A binary logistic regression study was performed to compare patients and controls and determine a predictive model of essential hypertension using the measured factors (the response variable is here denoted Y, which counts hypertensive subjects (D) and the controls (T), (D) being the reference value).

ROC curve was plotted to estimate the predictive capacity of our logistic model. P-value less than 0.05 was considered statistically significant.

Associations were quantified with odds-ratios (OR) and their 95% confidence intervals (CI). Several tests including Hosmer and Lemeshow were used to evaluate the adjustment's quality of the models. A significance level greater than 0.05 indicates that the model adjusts well the data and the model can be retained.

4. Results

In Table 1, Level 0 indicating a normal level of red blood cells (4–5.2 * 1012/l). Taking this factor into account in the logistic model, it appears in level 1 (below 4 * 1012/l) that these subjects have a three-and-a-half-fold risk to developing hypertension compared to those who have a normal rate of red blood cells. (OR = 3.64, 95% CI = 1.37–9.65, p < 0.05).

The risk of exposure to hypertension is reduced by one order in subjects with high level (level 2) of red blood cells compared to subjects with normal red blood cell count (OR = 0.07, 95% CI = 0.02–0.29, p = 0.000).

Our logistic model has retained the rate of MCV as a hematological factor associated with hypertension. we found that subjects who have MCV rate below 80 fl are more exposed to hypertension than subjects who have a normal rate (80–100 fl). with a risk that is thirteen and a half times greater (OR = 13.58, 95% CI = 4.68–39.41, p = 0.000).

The Mean Cell Hemoglobin concentration (MCHC), reveals that subjects who have a lower than normal rate of MCHC (<27 pg) are once less exposed to hypertension (OR = 0.04, 95% CI = 0.01–0.13, p = 0.000) compared to those who have a normal MCHC (27–34 pg).

For platelets, level 0 indicates a normal platelet count (140–400 * 109/l) while level 1 represents a lower platelet count than normal. Subjects at this level are twelve times more exposed to hypertension compared to subjects with normal platelet count (OR = 12.13, 95% CI = 1.45–101.18, significance level P = 0.021). However, for level 2 which represents a high platelet count (OR = 0.16, 95% CI = 0.03–0.78, significance level P = 0.024).

The risk of exposure to hypertension in these subjects is reduced by one compared to those who have a normal platelet count.

Finally, the increase in sedimentation rate at one hour increases the risk of hypertension by 56.63 times compared to subjects with normal sedimentation rate (OR = 56.63, 95% CI = 3.37–597.33, significance level P = 0.001).

Table 2 given an abstract of factors with more than two modalities effectively revealed from the logistic model. The Df indicates the number of modalities of the factor minus one. The nullity tests of the coefficients associated individually with each factor are very significant (p < 0.05), while the nullity tests of the coefficients associated simultaneously are also very significant (p < 0.05).

Table 3 justifies the choice of the model, including all tests of adequacy of the adjustment.- Pearson, hosmer-lemeshow, brown general alternative and brown symmetric alternative accept the logistic model (p >> 0.05).

Table 4 shows the predictive capabilities of this model. we found a very high percentage (91.4%) of concordant pairs.

The summary of the table of concordant and discordant pairs::

Table 2
Tests for terms with several degrees of freedom.

Terms	K-squire	Df	P
GRnx10*12/l	23,3950	2	0,000
PLn*109/l	11,0649	2	0,004

Key: Df: Degree of freedom.

Table 1
Logistic regression results.

Prédictors	Coefficients	Z (Wald)	P-value	OR	IC Min (95%)	IC Max (95%)
Constants	−4,39270	−3,63	0,000			
RBC Ratio *10^{12}/l						
1	1,29068	2,59	0,010	3,64	1,37	9,65
2	−2,72181	−3,62	0,000	0,07	0,02	0,29
MCV (fl)	2,60884	4,80	0,000	13,58	4,68	39,41
MCHC (pg)	−3,23787	−5,46	0,000	0,04	0,01	0,13
Platelets Ratio *10^{9}/l						
1	2,49573	2,31	0,021	12,13	1,45	101,18
2	−1,81620	−2,26	0,024	0,16	0,03	0,78
Sedimentation Rate (1 h/mm)	4,03651	3,36	0,001	56,63	5,37	597,33

Key: OR: Odds Ratio. **CI:** Confidence Interval. **fm:** Femtolitre. **pg:** Pico Gram. **1 h/mm:** Milimeter at one hour. **Min:** Minimum.**Max:** Maximum. **RBC:** Red Blood Cells. **MCV:** Mean Cell Volume. **MCHC:** Mean Cell Hemoglobin concentration.

Table 3
Tests of adequacy of the adjustment.

Methods	K-squire	Df	P
Pearson	40,5257	34	0,205
Sum of deviation squares	31,4982	34	0,591
Hosmer-Lemeshow	4,6685	6	0,587
Brown:			
general alternative	1,0187	2	0,601
symmetric alternative	0,2729	1	0,601

Key: Df: Degree of freedom.

Table 4
Measures of association: (between the response variable and the probability previsions).

Pairs	Number	Percentage	Recapitulative measures	
Concordant	12365	91,4	D of Somers	0,87
Discordant	648	4,8	Gamma of Goodman-Kruskal	0,9
Ex aequo	517	3,8	Tau a of Kendall	0,39
Total	13530	100,0		

The D of Somers, the Gamma of Goodman-Kruskal and Tau a of Kendall are measures generally between 0 and 1. The highest values show that the logistics model has strong prevision capabilities. In our case, the two first values of 0.87 and 0.9 implicate a very strong predictive capacity. The third (Tau a of Kendall) measure shows a relatively good predictive capacity.

5. ROC curve

The Receiving Operating Characteristics (ROC) group the true positive ratio TPR (TPR = sensitivity = True positives/positives) and the false positive ratio FPR (FPR = 1-specificity = False Positives/negatives) in Fig. 1.

Usually, we compare a p (w) at a level S = 0.5 to predict y (w), thus we can build the confusion matrix and exctrat the two predicted indicators TPR and FPR.

The ROC curve generalizes this idea by varying the entire continuum of all possible values of level 0 and 1. For each configuration we build the confusion matrix and calculate TPR and FPR. We get: Area under curve (AUC) = 0.90, which indicates exceptional discrimination between TPR and FPR.

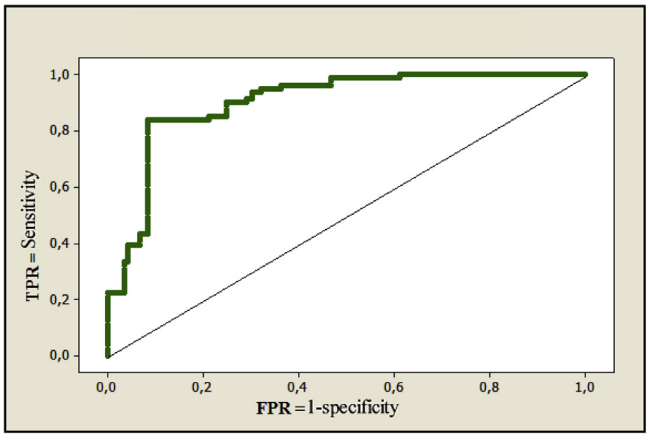

Fig. 1. ROC curve.

6. Discussion

Our study shows a statistically significant association between the risk of developing high blood pressure for both sexes and some hematological parameters, regardless of age, including:

Red blood cells ratio, MCV, MCHC, platelet ratio, and sedimentation ratio.

Our results show that subjects with fewer red blood cells have a three-and-a-half-fold risk of developing hypertension compared to those with normal blood pressure.

Many studies have shown that the anemic patients have a high prevalence of hypertension [7],.

The decrease in the number and life expectancy of red blood cells may be due to a deficit in the production of endogenous erythropoietin (EPO) by the kidneys. Indeed, EPO is a hormone that stimulates the production of red blood cells in the bone marrow [8].

Other changes may be involved in the development of arterial hypertension and in its pathogenesis.

There is a causal relationship between vascular function and different hematological disorders [9,10]. Most hypertensive patient's exhibit increased blood viscosity compared with healthy controls [11]. There is a decreased RBC deformability which could cause an increased microvascular flow resistance, which may result in haemolysis and organ damage [12]. This haemolysis induces release of Hgb in to the plasma which scavenges nitric oxide and causes endothelial dysfunction [13].

During hypertension very important alterations in rheological, mechanical and biochemical characteristics of erythrocytes and of blood flow have been shown. It is very relevant the increase in blood viscosity, the decrease in red blood cell (RBC) deformability, the formation of RBC “rouleaux” and RBC aggregates. These hemorheological determinants can favour an increase of peripheral resistances and of arterial blood pressure, causing or worsening hypertension [14].

Cicco G and Pirrelli A. have studied Red blood cell (RBC) deformability, RBC aggregability and tissue oxygenation in hypertension in 320 patients: In hypertensives, the authors found a decrease in erythrocyte deformability (evaluated with EI), in erythrocyte aggregation time, a fibrinogenaemia increase, an increase of shear rate to disaggregate erythrocytes, a decrease in cellular oxygen delivery and tissue oxygenation, an impairment of microcirculation. These changes may be involved in the development of arterial hypertension and in its pathogenesis. These patterns also are more impaired in hypertensives with diabetes, lipoidoproteinosis, etc. These patterns are not related with the age of the patients but they are significantly and directly related ($p < 0.01$) with the patient hypertension-age. This could be a new way to realize a better treatment in hypertensives and a prevention of cardiovascular complications (i.e.: myocardial infarction, …, etc.) [14].

More recently, Philippe Connes and Michel R Boisseau are intersted in the properties of erythrocyte deformability in various pathologies the authors found a decrease in plasma volume and thus a rise in systemic hematocrit and a high level of fibrinogen. The blood and plasma viscosities are high. This condition is observed during hypertension with reduction of microcirculatory peripheral beds.This reflects a loss of erythrocyte deformability which weakens the red blood cells thus causing a state of chronic anemia in these patients [15].

Furthermore, The Kaplan-Meier curves of one-year cardiovascular mortality in patients with hypertension, diabetes mellitus, chronic kidney stage ≧ 3, or advanced heart failure illustrated better results in the non-anemia group compared to anemia group (There was a significant difference between the non-anemia group and anemia group ($p < 0.001$) [16].

Our logistic model also retained the rate of MCV as a hematologic factor associated with hypertension. we found that subjects with lower MCV are more exposed to hypertension with a risk that is thirteen and a half times greater than subjects who have a normal MCV (80–100 fl), (OR = 13.58, 95% CI = 4.68–39.41, p = 0.000).

Old reports suggest that people with hypertension have lower MCVs than do subjects with normal blood pressure [17,18].

Rakotovao-Ravahatra ZD and al studied hemogram in hypertensive patients. Among 151 hypertensive patients, 41 per cent of them had microcytic anemias with MCV lower than normal [19]. Our study also shows that subjects who have MCHC lower than normal (<27 pg) are less exposed to hypertension (OR = 0,04; 95% CI = 0,01–0,13, p = 0,000).

In 2017, Enawgaw B and al conducted a comparative cross-sectional study of some hematological parameters of hypertensive and normotensive individuals [20].

In this study MCV and MCHC were increased significantly in hypertensive groups. But other studies in these parameters showed contradicted ideas. For example a study conducted by Babu KR et al. [3] showed significantly lower MCV and significantly higher MCHC. In São Paulo, Brazil, MCV were similar [21]. MCV is lower in group who receiving treatment with nondiuretics in elderly men (71–93 years of age) of the Honolulu Heart Program [22] and a study in Saudi Arabia showed no significant differences of MCV and MCHC [23] for platelets, subjects with lower than normal levels are 12 times more exposed to hypertension than subjects with normal platelet count (OR = 12.13, 95% CI = 1), 45–101.18, significance level P = 0.021) a correlation ($p = 0.010$) between platelet count and the severity of coronary artery disease was observed in the study of Hilal Bektas Uysal and al [24].

Additionally,in the study of Rakotovao-Ravahatra ZD and al, the results of the pathological hemograms show that 25.9 per cent of hypertensive patients had a decreased number of platelets [19]. Otherwise, In other studies, PLT count positively correlated with blood pressure indices (diastolic blood pressure, systolic blood pressure and mean arterial pressure) [20] according to the authors, The possible mechanisms might be related to vascular complication in hypertensive groups. High blood pressure causes endothelial damage via shear stress, which results in an increase in platelet activation [25].

We note also that, the increase in sedimentation rate at one hour increases the risk of hypertension by 56.63 times compared to subjects with normal sedimentation rate (OR = 56.63, 95% CI = 3.37–597.33, significance level P = 0.001).

Margret B. and al have tried to verify If erythrocyte Sedimentation Rate, is an Independent Predictor of Coronary Heart Disease and high blood pressure [26].

In this prospective population study, the authors have shown that ESR can independently predict the risk of developing Coronary Heart Disease. An increase in ln (ESR + 1) of one standard deviation predicted independently a 17 percent increase for men and an 18 percent increase for women in the risk of developing Coronary Heart Disease. For comparison, an increase in cholesterol of one standard deviation predicted independently a 34 percent increase in risk for men and a 27 percent increase in risk for women. ESR is therefore associated with approximately half of the increase in risk compared with cholesterol. Furthermore, the authors found that an increase of one standard deviation in ln(ESR + 1) increased the risk of death due to stroke by 23 percent ($p = 0.002$) for men and by 21 percent ($p < 0.001$) for women when adjusted for age and stage but that it decreased to 15 percent ($p = 0.06$) and 16 percent ($p = 0.08$), respectively, when adjusted for all risk factors [26].

The authors controlled for factors considered to influence ESR per se such as smoking, adiposity, socioeconomic indicators (as reflected by educational level), diabetes, and hemoglobin level as well as for other conventional Coronary Heart Disease risk factors to minimize the effect of confounding [26].

The Stockholm Prospective Study found erythrocyte sedimentation to be an independent risk factor for myocardial infarction [27].

This study comprised 3486 men followed up for 14 years and 171 incident cases of myocardial infarction.

Danesh and al. combined the results of available studies and found that a comparison of persons whose erythrocyte sedimentation values were in the top third compared with the bottom third yielded a risk ratio of 1.33 (95 percent CI: 1.15, 1.54) [28].

7. Conclusion

The profile of subjects at high risk for high blood pressure was established, using a logistic model for the detection of unknown cases. The hematological parameters significantly related to high blood pressure in both sexes are: red blood cells, MCV, MCHC, platelets blood ratio and sedimentation rate at one hour. The ROC curve justifies that the logistic model has a very strong forecasting capacity.

Competing interests

The author(s) declare no financial and non-financial interests.

Author contribution

Hamza Nadjib Merad-boudia (1): Writing of the main text, preparation of the tables and figure.

Majda Dali-Sahi (1): Supervise the work and write the summary.

Youcef Kachekouche (1): Calculations of the statistical part.

Nouria Dennouni-Medjati (1): Proofreading and correction of the manuscript.

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Abréviation list:

BP: Blood pressure
CAD: Coronary artery disease
CBC: Complete blood cell count
CKD: chronic kidney disease
DBP: Diastolic blood pressure
EI: Elongation Index
EDTA: Ethylene diamine tetra-acetate
ESR: erythrocyte sedimentation rate
HCT: Hematocrit
Hgb: Hemoglobin
HTN: Hypertension
MAP: Mean arterial pressure
MCH: Mean cell hemoglobin
MCHC: Mean cell hemoglobin concentration
MCV: Mean cell volume
MI: Myocardial infarction
MmHg: Millimeters mercury
MPV: Mean platelet volume
NO: Nitric oxide
PLT: Platelets
RBC: Red blood cells
RDW: Red blood cell distribution width
SBP: Systolic blood pressure
SCF: Stem cell factor
WBC: White blood cells