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Association of Angiotensin Converting Enzyme Gene Polymorphism and Possible High Risk Factors with Essential Arterial Hypertension in Egyptian Patients

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Abstract

Background: Hypertension (HT) is a public health challenge due to its high prevalence, and being a major risk factor for cardiovascular diseases. HT is a multifactorial disorder with genetic and environmental interactive factors.

Aim: This study aims to evaluate association of angiotensin converting enzyme gene polymorphism (I/D) with blood pressure among Egyptian patients with essential hypertension and the interrelationship with other clinical parameters.

Subjects and methods: Eighty four patients with essential hypertension were included in this cross sectional descriptive study. Venous blood samples were withdrawn for DNA extraction, determination of different genotypes of ACE gene (I/D) polymorphism by polymerase chain reaction (PCR) and measuring serum ACE levels, lipid profile, blood sugar and creatinin.

Results: The frequency of different ACE genotypes were; 41.7% homozygous (DD), 45.2% heterozygous (ID) and 13.1% homozygous (II) indicating that (D) allele is significantly associated with essential hypertension. Also serum ACE level was significantly correlated with ACE (I/D) polymorphism (p=0.001). Patients with DD genotype had the highest serum ACE level followed by patients with ID genotype and patients with II genotype had the lowest serum ACE level.

Conclusion: ACE (I/D) polymorphism is associated with increased serum ACE activity and consequently with increased risk for essential hypertension and its complications.

Keywords: Hypertension; Polymorphism; Multifactorial; Angiotensin converting enzyme; Polymerase chain reaction (PCR)

Abbreviations: ACE: Angiotensin Converting Enzyme; Ang II: Angiotensin II; ANOVA: One Way Analysis of Variance; BMI: Body Mass Index; bp: base pair

Introduction

Hypertension is a global public health issue as it contributes to the burden of heart diseases, stroke, kidney failure and premature mortality and disability. It disproportionately, affects populations in low-and middle-income countries where health systems are weak [1].

One billion of the world's population has hypertension, resulting in four million deaths per year [2,3]. Almost three-quarters of people with hypertension live in developing countries [4,5]. Furthermore, the prevalence of hypertension is increasing and is predicted to grow by more than 500 million by 2025 [3,6].

The Egyptian National Hypertension Project (NHP, 1991) provided estimates of hypertension prevalence, awareness, treatment and control among Egyptians. Data from the NHP showed that, hypertension is common among Egyptians and appeared to be slightly more common in Egyptian women (28.9%) than men (25.7%) [7-10].

Approximately 30% of the inter-individual variability in blood pressure is genetically determined [11]. Numerous studies have focused on the role of genetic variation in genes implicated in the renin-angiotensin system (RAS), particularly the angiotensin-converting enzyme (ACE) gene [12]. ACE is the core enzyme in the RAS catalyzing the production of angiotensin II (Ang II) which is the key effector in RAS due to its role in blood pressure regulation, salt-water balance and angiotasis [13,14].

Concentrations of plasma and tissue ACE are determined by the ACE gene located on chromosome 17q23 [12]. This gene is polymorphic and shows inconsistent association with arterial blood pressure. An insertion/deletion (I/D) polymorphism in intron 16 (287 bp) of the ACE gene gives rise to 3 genotypes; the homozygotes II and DD, and the heterozygote ID. It has been suggested that this polymorphism could explain up to 47% of total phenotypic variation in ACE serum levels and determines ACE enzyme activity [12].

This study aims to evaluate association of angiotensin converting enzyme gene polymorphism (I/D) with blood pressure among Egyptian patients with essential hypertension and the interrelationship with other clinical parameters such as ACE serum activity, fasting blood sugar, lipid profile, creatinine and body mass index (BMI).

Methods

Study participants

The study was a cross sectional descriptive study and included 84 patients (20 male and 64 female) selected by a convenient sampling. Their mean age was 55 years old and diagnosed with essential arterial hypertension according to JNC7, 2003 [15]. They were recruited from the Cardiology Clinic, Suez Canal University Hospital, Ismailia, Egypt. All participants had no history of cardiac diseases, renal problems or diabetes mellitus. Arterial blood pressure was measured and body mass

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index (BMI) was calculated for each patient. The study was approved by the Medical Research Ethics Committee of the Faculty of Medicine, Suez Canal University and all patients were given written informed consent.

Sample collection and processing

A 5 ml venous blood sample was withdrawn from each patient after 8-12 h fasting. 2 ml of whole blood were collected into potassium EDTA tubes for DNA extraction and determination of different genotypes of ACE gene (I/D) polymorphism by polymerase chain reaction (PCR). The remaining 3 ml were collected into plain tubes and used for serum separation for measurement of fasting blood glucose (FBG), lipid profile {triglycerides (TG), total cholesterol, HDL-C and LDL-C}, creatinine and serum ACE levels.

Molecular analysis of blood samples

DNA extraction: Genomic DNA was extracted from 300 µl of whole blood collected in potassium EDTA tubes using the Wizard® genomic DNA purification kit (Promega, Madison, USA, Cat.# A1120) and DNA concentration and purity were measured by NanoDrop ND-1000 spectrophotometer (NanoDrop Tech., Inc. Wilmington, D/C, USA).

ACE (I/D) genotyping by thermal cycler PCR: A fragment of 287 base pairs (bp) in intron 16 of ACE gene was amplified with forward primer 5'-CTG GAG ACC ACT CCC ATC CTT TCT -3' and reverse primer 5'-GAT GTG GCC ATC ACA TTC GTC AGA T-3' [16]. PCR was carried out in Eppendorf Mastercycler® machine (Eppendorf AG, Hamburg, Germany) using GoTaq® G2 Green Master Mix (Promega, Madison, USA, cat.# M7822) which is a premixed ready-to-use solution containing GoTaq® G2 DNA Polymerase, 400 µM dATP, 400 µM dGTP, 400 µM dCTP, 400 µM dTTP, reaction Buffer (pH 8.5) and 3 mM $MgCl_2$. The PCR reaction was carried out in a final volume of 25 µl including; 12.5 µl GoTaq® G2 Green Master Mix, 1 µl forward primer, 1 µl reverse primer, 1 µl DNA template and 9.5 µl nuclease-free water. Thermal cycling conditions of PCR reaction were 30 cycles of denaturation at 94°C, annealing at 58°C and extension at 72°C, each for 1 min. PCR products were analyzed by electrophoresis in 2% agarose gel (w/v) and the gel was visualized by ultraviolet trans-illumination and photographed after staining with ethidium bromide. A 100 base pair (bp) DNA marker was loaded into the gel to determine the length of PCR products which were of 490 bp for I allele and 190 bp for D allele (Figure 1).

Measurement of serum ACE level: Serum ACE level was measured using human EIAab®ACE ELISA kit (Wuhan EIAab Science Co.,Ltd, China) Cataloge No: E0004h.

Biochemical tests

FBG [17], Triglycerides (TG) [18], Total cholesterol [19], High density lipoprotein-cholesterol (HDL-C) [20] were all measured by enzymatic colorimetric method using Biodiagnostic kit. Creatinine was measured by Colorimetric kinetic method using Biodiagnostic kit [21].

Statistical analysis

Data were managed using the "Statistical Package for Social Sciences (SPSS)", version 17.0 software. Descriptive statistics were represented as mean ± standard error (SE) for quantitative variables. Associations of genotypes with the biochemical tests and serum ACE level were analyzed by one way analysis of variance (ANOVA) test followed by Tukey's test for multiple comparisons. Relationships of serum ACE level with the component of the biochemical tests in the study population were assessed using Pearson's correlation coefficient analyzed by the bivariate correlations method. Confidence interval (CI) and odds ratio (OD) were determined to assess the strength of association and the reliability of the estimated results. A value of $p<0.05$ was considered statistically significant.

Results

Characteristics of the study patients

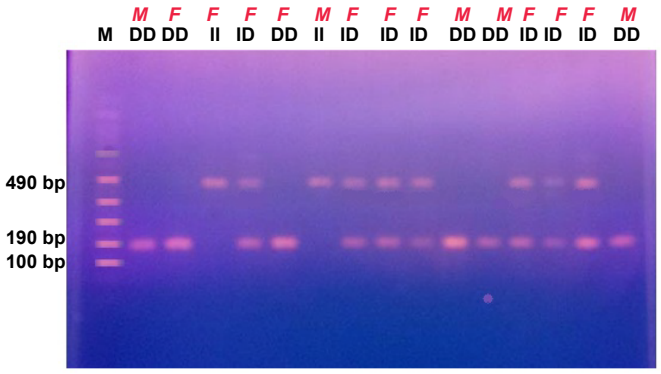
The mean age of the patients was 55 years old. Most of them were females (76.2%); the others (23.8%) were males. There was a slight difference between males and females in their body mass index, Systolic and diastolic pressures are slightly higher in females than males; however these differences are not statistically significant (Table 1).

Lipid profile, fasting blood glucose and serum creatinine levels were measured for all patients. Male hypertensive patients showed higher levels of total cholesterol, low density lipoprotein, triglycerides and fasting blood glucose, whereas female patients showed higher levels of high density lipoprotein and serum creatinine. However, the observed sex differences were not statistically significant except for a significant difference between males and females in their fasting blood sugar level ($p=0.033$).

The mean serum ACE level of patients was 4.6 mg/dL and also there was no significant difference in serum ACE level between males and females.

Association of ACE gene (I/D) polymorphism with essential hypertension

The frequency of different ACE genotypes is showed in (Figure 2 and Table 2). The (DD) homozygous were 41.7% {11.9% male and 29.8% female}, the heterozygous (ID) were 45.2% {10.7% male and



M: 100 bp marker, **D** allele 190 bp and **I** allele 490 bp; F (Female), M (Male)

Figure 1: Amplified portion angiotensin converting enzyme (ACE) gene on 2% agarose gel.

Variable	Male 20 (23.8%)	Female 64 (76.2%)	Total 84 (100%)	p value
Age (years)	55.70 ± 2.43	55.92 ± 1.33	55.87 ± 1.16	0 .741
BMI (kg/m²)	28.43 ± 0.48	29.25 ± 0.76	28.60 ± 0.40	0.001
Systolic blood pressure (mm Hg)	140.50 ± 3.51	142.97 ± 2.53	142.38 ± 2.09	0 .254
Diastolic blood pressure (mm Hg)	90.00 ± 1.92	91.25 ± 0.95	90.95 ± 0.86	0.669

Data are represented as mean ± SE. BMI=Body Mass Index

Table 1: Clinical characteristics of the hypertensive patients (n=84).

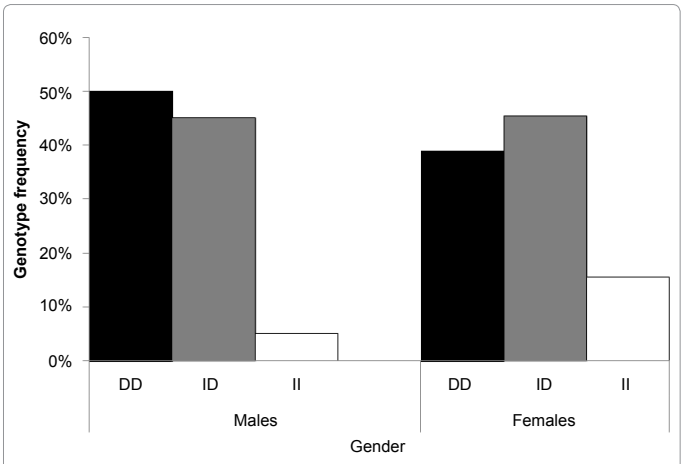


Figure 2: Genotypes of angiotensin converting enzyme (ACE) gene polymorphism (I/D) in patients of different sexes.

	Total (n=84)	Male (n=20)	Female (n=64)	P value
Genotype	**N (%)**	**N (%)**	**N (%)**	
DD	35 (41.7%)	10 (11.9%)	25 (29.8%)	0.582
ID	38 (45.2%)	9 (10.7%)	29 (34.5%)	
II	11 (13.1%)	1 (1.2%)	10 (11.9%)	
Total	84 (100%)	20 (23.8%)	(76.2%)	

Data are represented by number (n) and percentage (%). Student T-test was used

Table 2: Genotypes of ACE gene polymorphism (I/D) in patients.

34.5% female}, and the homozygous (II) were 13.1% {1.2% male and 11.9% female}. The frequency of the high risk allele (D) was 64.3% while the frequency of the low risk allele (I) was 35.7% indicating that (D) allele is significantly associated with essential hypertension.

Association of ACE gene (I/D) polymorphism with clinical data & lab findings of the patients

The high risk DD genotype groups showed a significant increase in BMI than ID and II genotype carriers ($p<0.001$), whereas the II genotype showed the least BMI in both sexes. Males of the II genotype are at a higher risk of a higher systolic blood pressure and nearly so with regard to diastolic blood pressure compared with the other genotypes. Heterozygotes for the DI alleles seem to be at much lower risk concerning systolic and diastolic blood pressure compared with the homozygote types (Table 3).

Homozygotes for DD alleles had the highest level of total cholesterol, triglycerides and low density lipoprotein compared to D/I and II genotypes. The heterozygote D/I had intermediate values between the DD and II homozygotes (Table 4). The situation is the reverse for high density lipoprotein where II homozygote genotype showed the highest level compared with D/I and DD genotypes. All Observed differences between the different genotypes: DD, DI and II, are statistically significant. Male and female hypertensive patients in this group show the same trend of changes in the measured levels. There seem to be no differences between males and females in the biochemical estimates of lipid profile and triglycerides.

Homozygous of the DD genotype had significantly higher blood glucose levels than carriers of the ID genotype ($p=0.003$ in total FBS and $p=0.034$ in females only) (Table 5), the data suggest that the similarity of blood glucose level between II and D/I genotypes points to dominance of the I allele over the D allele in that respect.

The level of serum creatinine was similar in the different genotypes which suggest no contribution or association between the angiotensin gene ACE and serum creatinine (Table 5).

Correlation between serum ACE levels, ACE I/D polymorphism and clinical data of the patients

Serum ACE level was significantly associated with ACE I/D polymorphism. Patients with DD genotype had the highest serum ACE level (6.03 ± 0.08 ng/ml), followed by patients with ID genotype (4.19 ± 0.14 ng/ml), and patients with II genotype had the lowest serum ACE level (1.48 ± 0.26 ng/ml) (Figure 3).

Serum ACE level showed significant positive correlation with BMI, TG, total cholesterol, LDL-C and FBG and showed significant negative correlation with HDL-C (Figure 4). On the other hand, hypertensive patients of the II genotype show positive association with HDL. This indicates that the high level of HDL represents a high risk for II homozygotes.

Discussion

The distribution of different genotypes of the ACE gene within

Variables	DD Homozygots (n=35)	Carriers of ID (n=38)	II Homozygots (n=11)
Age (year)	57 ± 1.52	55 ± 1.70	55 ± 4.67
BMI (kg/m^2) Total	32.08 ± 0.52*	26.87 ± 0.12*	23.74 ± 0.45*
Male	32.57 ± 1.06*	26.89 ± 0.38*	22.65 ± 1.38*
Female	31.82 ± 0.58*	26.86 ± 0.13*	23.99 ± 0.47*
Systolic blood pressure (mm Hg) Total	138.28 ± 2.37	145.52 ± 3.67	144.54 ± 5.93
Male	140.83 ± 3.13	136.67 ± 6.15	155.00 ± 14.99
Female	136.96 ± 3.32	147.19 ± 4.17	142.22 ± 6.62
Diastolic blood pressure (mm Hg) Total	90.28 ± 1.26	91.05 ± 1.40	92.72 ± 1.95
Male	89.17 ± 1.93	88.33 ± 3.07	95.00 ± 4.99
Female	90.87 ± 1.65	91.56 ± 1.56	92.22 ± 2.22

Data are presented as mean ± SE. Comparisons were performed with one way ANOVA test followed by the Tukey's test for multiple comparison.BMI=Body Mass Index; * indicates significant difference

Table 3: The relationship between *ACE* genotypes and the clinical characteristics in the study population.

Variables	DD Homozygots (n=35)	Carriers of ID (n=38)	II Homozygots (n=11)
TG (mg/dL) Total	231.67 ± 2.29	191.74 ± 1.90*	160.54 ± 3.19*#
Male	229.52 ± 4.26	192.49 ± 5.01*	166.67 ± 4.86*#
Female	232.79 ±2.72	191.60 ± 2.09*	159.18 ± 3.69*#
Total cholesterol (mg/dL)	243.04 ± 3.15	194.59 ± 2.45*	150.61 ± 4.29 *#
Male	250.83 ± 5.77	189.21 ± 7.84*	153.50 ± 7.44*#
Female	238.98 ± 3.52	195.60 ± 2.54*	149.96 ± 5.12*#
HDL –C (mg/dL) Total	36.71 ± 0.82	49.50 ± 0.81*	67.68 ± 1.54*#
Male	33.46 ± 1.63	47.27 ± 1.84*	69.78 ± 6.94*#
Female	38.40 ± 0.70	49.92 ± 0.89*	67.21 ± 1.46*#
LDL-C (mg/dL) Total	160.0 ± 3.15	106.74 ± 2.76*	50.82 ± 3.79*#
Male	171.46 ± 4.74	103.45 ± 9.12*	50.86 ± 0.47*#
Female	154.02 ± 3.56	107.36 ± 2.86*	50.92 ± 4.68*#

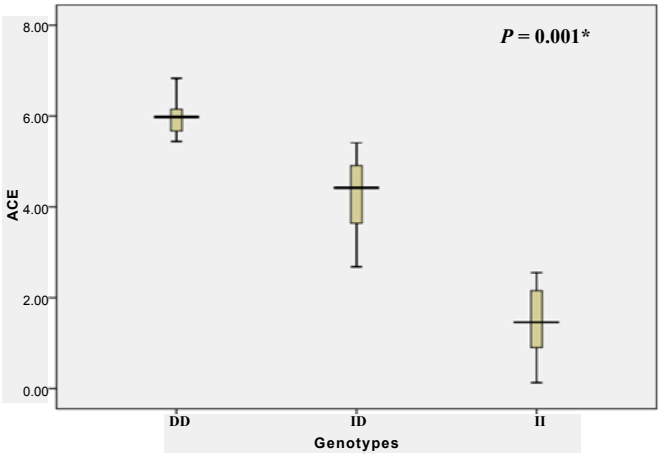
Data are presented as mean ± SE. Comparisons were performed with one way ANOVA test followed by the Tukey's test for multiple comparison. HDL-C=High Density Lipoprotein Cholesterol; LDL-C=Low Density Lipoprotein Cholesterol; TG=Triglycerides; * indicates significant difference from homozygous of DD; # indicates significant difference from carriers of ID

Table 4: The Lipid profiles of carriers of the different genotypes of *ACE* gene in the study population.

Variables	DD Homozygots (n=35)	Carriers of ID (n=38)	II Homozygots (n=11)
FBG (mg/dL) Total	116.26 ± 9.52	82.50 ± 4.93*	87.04 ± 6.58
Male	126.22 ± 18.26	78.78 ± 4.99	112.69 ± 28.98
Female	111.07 ± 11.08	83.19 ± 5.80*	81.34 ± 4.53
Creatinine (mg/dL) Total	1.10 ± 0.12	1.02 ± 0.09	1.27 ± 0.21
Male	1.04 ± 0.25	1.05 ± 0.20	1.05 ± 0.35
Female	1.13 ± 0.13	1.01 ± 0.09	1.32 ± 0.25

Data are presented as mean ± SE. Comparisons were performed with one way ANOVA test followed by the Tukey's test for multiple comparison. FBG=Fasting Blood Glucose Level; * indicates significant difference from homozygous of DD

Table 5: Other laboratory investigations of carriers of the different genotypes of *ACE* gene in the study population.



Data are presented as mean ± SE
*indicates significant difference from carriers of DD

Figure 3: Serum angiotensin converting enzyme (ACE) level in carriers of the different genotypes of ACE gene polymorphism.

the studied hypertensive group was in Hardy-Weinberg equilibrium, indicating that the selected sample was representative. The frequency of homozygous for (DD) was 41.7% whereas the frequency of homozygous for (II) was 13.1%. Heterozygous (ID), were constituting the relatively larger group 45.2%. These results suggest that allele (D) with a frequency of 64.3% is the high risk allele and allele (I) with a frequency of 35.7% is the low risk allele significantly associated with essential hypertension. These findings are in agreement with the results reported by Ji et al. [22]; Ali et al. [23]; Zarouk et al. [24], who noted that hypertensive cases showed a significantly higher frequency of the ACE mutant D allele carriage than the I allele carriage among Chinese, Saudi Arabia and Egyptian populations, respectively. Also a significant association of the ACE gene D allele with essential hypertension was documented in an African-American [25], Chinese [26], and Japanese populations [27,28]

However, the findings of Rasyid et al. [29] and Kabadou et al. [30], are inconsistent with the above mentioned reports as no significant association between ACE (D) allele and hypertension in a South Sulawesi Indonesian and a Tunisian populations, respectively was observed. Also, ACE I/D polymorphism was reported as negatively associated with hypertension in Emirati Arabs, Dutch, Spanish, and Cuban populations [31-35].

On the other hand, allele (I) was found to be associated with high blood pressure in an Australian population with strong evidence of familial hypertension [36].

The noted population variability in the association of ACE I/D polymorphism with essential hypertension has been suggested to be due to significant variations of population backgrounds such as different sample size, different criteria specifically clinical presentation, age and age onset of the disease, ethnic background, geographical area and concomitant environmental and social risk factors [37].

The serum ACE level in the studied group was significantly correlated with ACE I/D polymorphism. Patients with DD genotype had the highest serum ACE level (6.03 ± 0.48 ng/ml), and patients with II genotype had the lowest serum ACE level (1.48 ± 0.86 ng/ml), whereas patients with ID genotype had intermediate values (4.19 ± 0.84 ng/ml), These results are in agreement with the findings of Rigat et al. [38]; Park et al. [39]; Camós et al. [40], in Caucasian, Korean and Spanish populations, respectively. In contrast to these findings, Ljungberg et al. [41]; He et al. [42], found that serum ACE activities were highest in II carriers, than in DD carriers, and lowest in ID carriers among South East Sweden and Chinese populations, respectively.

No significant differences of ACE I/D genotype distribution or Serum ACE level between males and females were noted in subjects of this study. These results are in agreement with the findings of Kruit et al. [43]; Zhang et al. [44], but differ from those reported by Sagnella et al. [45], who observed a significant association between the D allele and hypertension in women of African descent. Also, Renée et al. [46], found significant genotype–sex interactions among Mexican American females, but not males. Katsuya et al. [47]; O'Donnell et al. [48], found that D allele has been associated with hypertension in white American and Japanese men but not in women.

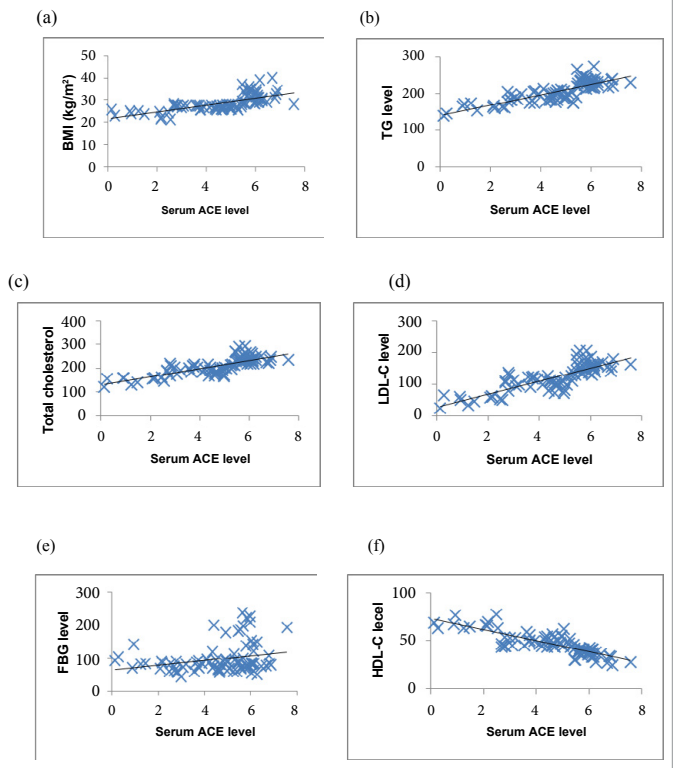


Figure 4: Correlation between serum angiotensin converting enzyme (ACE) level and different clinical parameters of the patients, TG, TC, HDL-C, LDL-C and FBG (mg/dl).

The potential role of ACE gene (I/D) polymorphism and thus of differential ACE plasma activity in the development of hypertension is still a matter of controversy [49,50]. Other environmental risk factors seem to be good candidates for causing the observed elevation in the arterial blood pressure in different I/D genotypes.

The serum ACE level showed a significant positive correlation with BMI, TG, total cholesterol, LDL-C and FBG, but it showed a significant negative correlation with HDL-C which is consistent with the findings of He et al. [42]; Ajala et al. [51]. On the other hand, Overlack et al. [52]; Persu et al. [53], suggested that the level of serum ACE activity is not of pathophysiolgical or clinical significance in essential hypertension as they confirmed the hypothesis that the membrane-bound ACE, instead of circulating ACE, was responsible for Angiotensin II generation and its cardiovascular consequences. Our results are in agreement and support of the contention that ACE serum level cannot be taken as an immediate risk factor in hypertension as both the I/I homozygotes and the D/I heterozygotes have statistically significant lower level of the enzyme in the hypertensive patients. A finding which suggests the presence of other confounding environmental factors which increased the risk for developing the hypertensive condition. The observed positive association of the hypertensive II homozygotes with higher levels of HDL points to the high risk factor of the latter factor. These findings suggest that hypertensive D/I heterozygotes stand a higher risk than either homozygotes DD and II as being exposed to either or both high ACE level or high HDL or both.

The normal distribution of ACE gene polymorphism (I/D) among two Egyptian populations of different ethnic groups was reported by [54]. The two Egyptian populations showed a high frequency of the ACE D allelle (0.67). Another study by Zarouk et al. [24] reported significant association between DD genotype and D allele with hypertension in Egyptian patients. The study sample in the above two studies on Egyptians failed to describe data concerning their age, gender and inclusion or exclusion criteria.

These findings can be of great value in the management of hypertension whether the determining risk factor is the high level of serum ACE or is due to high level of HDL and proper treatment will be described according to these findings.

Conclusion

ACE gene polymorphism could be a molecular marker for hypertension as ACE gene (I/D) polymorphism is strongly associated with an increased risk for hypertension and its complications. The genetic predisposition of the DD, DI and II genotypes seems to be associated with specific environmental risk factors particularly serum ACE level, and high HDL, which play a significant role in the elevation of blood pressure leading to the clinical manifestations of hypertension. Knowledge of the ACE gene polymorphism and the two risk factors; ACE serum level and HDL will improve the treatment and management of essential hypertension.

Conflict of Interest

All authors (ER, EM, AZ and FM) declare that the research was conducted in the absence of any commercial or financial relationships that could be considered as a potential conflict of interest. Also no one of the authors have any non-financial competing interests.

Authors' Contribution

ER, EM, FM Conceived and designed the experiments: ER, AZ. Collected samples and data: ER Performed the experiments: ER, EM, FM Analyzed the data: ER & FM wrote the paper: ER, EM, FM. Critical revision: NR, EM, FM. Final approval: EM, AZ, FM.

References

1. World Health Organization WHO (2013) A global brief on hypertension silent killer, global public health crisis.
2. World Health Organization WHO (2004) Report on the regional consultation on hypertension prevention and control.
3. Kearney PM, Whelton M, Reynolds K, Muntner P, Whelton PK, et al. (2005) Global burden of hypertension: Analysis of worldwide data. Lancet 365: 217-223.
4. World Health Organization WHO (2002) The world health report: Reducing risks, promoting healthy life. Geneva.
5. World Health Organization WHO (2005) Global Report: Preventing chronic disease: A vital investment. Geneva.
6. Fuentes R, Ilmaniemi N, Laurikainen E, Tuomilehto J, Nissinen A (2000) Hypertension in developing economies: A review of population-based studies carried out from 1980 to 1998. J Hypertens 18: 521-529.
7. Ibrahim MM, Rizk H, Appel LJ, el Aroussy W, Helmy S, et al. (1995) Hypertension prevalence, awareness, treatment and control in Egypt. Results from the Egyptian National Hypertension Project (NHP). NHP Investigative Team. Hypertension 26: 886-890.
8. Ibrahim MM (1997) Hypertension surveys in the developing world. Lessons from the Egyptian National Hypertension Project (NHP). J Hum Hypertens 11: 709-726.
9. Ibrahim MM (1999) Epidemiology of hypertension in Egypt. Saudi J Kidney Dis Transpl 10: 352-356.
10. Ibrahim MM, Damasceno A (2012) Hypertension in developing countries. Lancet 380: 611-619.
11. Ward R (1995) Familial aggregation and genetic epidemiology of blood pressure. Hypertension: Pathophysiology, Diagnosis and Management. New York: Raven Press 67-68.
12. Hubert C, Houot AM, Corvol P, Soubrier F (1991) Structure of the angiotensin I-converting enzyme gene. Two alternate promoters correspond to evolutionary steps of a duplicated gene. J Biol Chem 266: 15377-15383.
13. Soldner A, Spahn-Langguth H, Mutschler E (1996) The renin-angiotensin-aldosterone system: Focus on its distinct role in arterial hypertension and its various inhibitors as a therapeutic strategy to effectively lower blood pressure. Pharmazie, 51:783-799.
14. Ferrario CM, Strawn WB (2006) Role of the renin-angiotensin-aldosterone system and proinflammatory mediators in cardiovascular disease. Am J Cardiol 98: 121-128.
15. Chobanian AV, Bakris GL, Black HR, Cushman WC, Green LA, et al. (2003) Seventh report of the Joint National Committee on Prevention, Detection, Evaluation and Treatment of High Blood Pressure. Hypertension (Joint National Committee on Prevention) 6: 1206–1252.
16. Tiret L, Rigat B, Visvikis S, Breda C, Corvol P, et al. (1992) Evidence, from combined segregation and linkage analysis, that a variant of the angiotensin I-converting enzyme (ACE) gene controls plasma ACE levels. Am J Hum Genet 51: 197-205.
17. Trinder P (1969) Determination of glucose in blood using glucose oxidase with an alternative oxygen acceptor. Annals of Clinical Biochemistry 6: 24-27.
18. Fossati P, Prencipe L (1982) Serum triglycerides determined colorimetrically with an enzyme that produces hydrogen peroxide. Clinical Chemistry 28: 2077-2080.
19. MacLachlan J, Wotherspoon AT, Ansell RO, Brooks CJ (2000) Cholesterol oxidase: Sources, physical properties and analytical applications. J Steroid Biochem Mol Biol 72: 169-195.
20. Burstein M, Scholnick HR, Morfin R (1970) Method for the Isolation of lipoproteins from human serum by precipitation with polyanions. Journal of Lipid Research 11: 583-595.
21. Murray RL, Creatinine, Kaplan A (1984) Clinical chemistry. The C.V. Mosby Co. St.Louis. Toronto. Princeton, pp: 418, 1261-1266.
22. Ji LD, Zhang LN, Shen P, Wang P, Zhang YM (2010) Association of

angiotensinogen gene M235T and angiotensin-converting enzyme gene I/D polymorphisms with essential hypertension in Han Chinese population: A metaanalysis. J Hypertens 28: 419–428.

23. Ali A, Alghasham A, Ismail H, Dowaidar M, Settin A (2013) ACE I/D and eNOS E298D gene polymorphisms in Saudi subjects with hypertension. J Renin Angiotensin Aldosterone Syst 14: 348-353.

24. Zarouk WA, Hussein IR, Esmaeil NN, Raslan HM, Reheim HA, et al. (2012) Association of angiotensin converting enzyme gene (I/D) polymorphism with hypertension and type 2 diabetes. Bratisl Lek Listy 113: 14-18.

25. Duru K, Farrow S, Wang JM, Lockette W, Kurtz T (1994) Frequency of a deletion polymorphism in the gene for angiotensin converting enzyme is increased in African-Americans with hypertension. Am J Hypertens 7: 759-762.

26. Chiang FT, Chem TH, Lai ZP, Tseng CD, Hsu KL, et al. (1996) Age and gender dependent association of the angiotensin-converting enzyme gene with essential hypertension in a Chinese population. J Hum Hypertens 10: 823-826

27. Nakano Y, Oshima T, Hiraga H, Matsuura H, Kajiyama G, et al. (1998) DD genotype of the angiotensin I-converting enzyme gene is a risk factor for early onset of essential hypertension in Japanese patients. J Lab Clin Med 131: 502-506.

28. Morise T, Takeuchi Y, Takeda R (1994) Angiotensin-converting enzyme polymorphism and essential hypertension. Lancet 343: 125.

29. Rasyid H, Bakri S, Yusuf I (2012) Angiotensin-converting enzyme gene polymorphisms, blood pressure and pulse pressure in subjects with essential hypertension in a South Sulawesi Indonesian population. Acta Med Indones 44: 280-283.

30. Kabadou IA, Soualmia H, Jemaa R, Feki M, Kallel A (2013) G protein beta3 subunit gene C825T and angiotensin converting enzyme gene insertion/deletion polymorphisms in hypertensive Tunisian population. Clin Lab 59: 85-92.

31. Frossard PM, Hill SH, Elshahat YI, Obineche EN, Bokhari AM, et al. (1998) Associations of angiotensinogen gene mutations with hypertension and myocardial infarction in a gulf population. Clin Genet 54: 285-293.

32. Takami S, Katsuya T, Rakugi H, Sato N, Nakata Y, et al. (1998) Angiotensin II type 1 receptor gene polymorphism is associated with increase of left ventricular mass but not with hypertension. Am J Hypertens 11: 316-321.

33. van den Born BJ, van Montfrans GA, Uitterlinden AG, Zwinderman AH, Koopmans RP (2007) The M235T polymorphism in the angiotensinogen gene is associated with the risk of malignant hypertension in white patients. J Hypertens 25: 2227-2233.

34. Poch E, de La Sierra A, González-Núñez D, Oriola J, Redón J, et al. (2002) Genetic polymorphisms of the renin-angiotensin system and essential hypertension. Med Clin (Barc) 118: 575-579.

35. Companioni Nápoles O, Sautié Castellanos M, Leal L, Casalvilla R, Camacho H, et al. (2007) ACE I/D polymorphism study in a Cuban hypertensive population. Clin Chim Acta 378: 112-116.

36. Zee RY, Lou YK, Griffiths LR, Morris BJ (1992) Association of a polymorphism of the angiotensin I-converting enzyme gene with essential hypertension. Biochem Biophys Res Commun 184: 9-15.

37. Barley J, Blackwood A, Cartere ND, Crew DE, Cruickshank JK, et al. (1994) Angiotensin converting enzyme insertion/deletion polymorphism: Association with ethnic origin. J Hypertes 12: 955-957.

38. Rigat B, Hubert C, Alhenc-Gelas F, Cambien F, Corvol P (1990) An insertion/deletion polymorphism in the angiotensin I-converting enzyme gene accounting for half the variance of serum enzyme levels. J Clin Invest 86: 1343-1346.

39. Park EY, Ahn HM, Lee JA (2009) Insertion/deletion polymorphism of angiotensin converting enzyme gene in Korean hypertensive adolescents. Heart Vessels, 24: 193-198

40. Camos S, Cruz MJ, Morell F, Sole E (2012) Genetic-based reference values for angiotensin-converting enzyme (ACE) according to I/D polymorphism in a Spanish population sample. Clin Chem Lab Med 50: 1749-1753.

41. Ljungberg L, Alehagen U, Länne T, Björck H, De Basso R (2011) The association between circulating angiotensin-converting enzyme and cardiovascular risk in the elderly: A cross-sectional study. J Renin Angiotensin Aldosterone Syst 12: 281-289.

42. He Q, Fan C, Yu M, Wallar G, Zhang ZF (2013) Associations of ACE gene insertion/deletion polymorphism, ACE activity and ACE mRNA expression with hypertension in a Chinese population. PLoS ONE 8: e75870.

43. Kruit A, Grutters JC, Gerritsen WB, Kos S, Wodzig WK, et al. (2007) ACE I/D-corrected Z-scores to identify normal and elevated ACE activity in sarcoidosis. Respir Med 101: 510-515.

44. Zhang Y, Qiong Cheng, Nelson LS Tang, Tanya TW Chu, Brian Tomlinson, et al. (2013) Gender difference of serum angiotensin-converting enzyme (ACE) activity in DD genotype of ACE insertion/deletion polymorphism in elderly Chinese. Journal of Renin-Angiotensin-Aldosterone System 0: 1-6.

45. Sagnella GA, Rothwell MJ, Onipinla AK (1999) A population study of ethnic variations in the angiotensin-converting enzyme I/D polymorphism: Relationships with gender, hypertension and impaired glucose metabolism. J Hypertens 17: 657-664.

46. Renee M Ned, Yesupriya A, Imperatore G, Smelser DT, Moonesinghe R, et al. (2011) The ACE I/D polymorphism in US adults: Limited evidence of association with hypertension-related traits and sex-specific effects by race/ethnicity. American Journal of Hypertension 25: 209-215.

47. Katsuya T, Horiuchi M, Chen YD, Koike G, Pratt RE, et al. (1995) Relations between deletion polymorphism of the angiotensin-converting enzyme gene and insulin resistance, glucose intolerance, hyperinsulinemia and dyslipidemia. Arterioscler Thromb Vasc Biol 15:779-782.

48. O'Donnell CJ, Lindpaintner K, Larson MG, Rao VS, Ordovas JM, et al. (1998) Evidence for association and genetic linkage of the angiotensin-converting enzyme locus with hypertension and blood pressure in men but not women in the Framingham Heart Study. Circulation 97: 1766-1772.

49. Sayed-Tabatabaei FA, Oostra BA, Isaacs A, van Duijn CM, Witteman JC (2006) ACE polymorphisms. Circ Res 98: 1123-1133.

50. Nawaz SK, Hasnain S (2009) Pleiotropic effects of ACE polymorphism. Biochemia Medica 19: 36-49.

51. Ajala AR, Almeida SS, Rangel M, Palomino Z, Strufaldi MW (2012) Association of ACE gene insertion/deletion polymorphism with birth weight, blood pressure levels and ACE activity in healthy children. Am J Hypertens 25: 827-832.

52. Overlack A, Higuchi M, Kolloch R, Stumpe KO (1983) Converting enzyme activity and essential hypertension. Klin Wochenschr 61: 377-378.

53. Persu A, Lambert M, Deinum J, Cossu M, de Visscher N (2013) A novel splice-site mutation in angiotensin I-converting enzyme (ACE) gene, c.3691+1GA (IVS25+1G>A), causes a dramatic increase in circulating ace through deletion of the transmembrane anchor. PLOS ONE 8: e59537.

54. Salem AH (2008) Distribution of angiotensin converting enzyme insertion/deletion gene polymorphism among two Arab populations. Suez Canal Univ Med J 11: 125-130.