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The influence of vitamin D, vitamin K, and parathyroid hormone on anemia severity in chronic kidney disease patients undergoing hemodialysis

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ABSTRACT

Patients undergoing hemodialysis for end-stage renal disease (ESRD) frequently have anemia. Disruptions in vitamin D and vitamin K metabolism, along with alterations in parathyroid hormone levels, may influence the severity of anemia in this population. This study investigated the impact of vitamin D, vitamin K, and parathyroid hormone (PTH) levels on the severity of patients with ESRD undergoing maintenance hemodialysis. The Hamida Al-Masfah Dialysis Centre at Al-Imamain Al-Kadhimain Teaching Hospital in Baghdad conducted a prospective cross-sectional study from November 1, 2023, to April 20, 2024. One hundred standard hemodialysis patients aged 18 years or older were recruited. Patients were classified based on anemia severity (Hb<8 g/dL versus Hb ≥8 g/dL) and PTH levels (<150 versus 150-600 pg/mL). ELISA quantified 25(OH)D, vitamin K, and intact PTH in the serum. Statistical techniques were employed for correlation and comparative analyses. Patients with severe anemia exhibited markedly reduced mean 25(OH)D levels (p=0.02). The levels of PTH and vitamin K were comparable throughout the anaemic groups (p=0.11

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and 0.66 respectively). A strong inverse connection was identified between serum 25(OH)D and PTH levels (p=0.03). Furthermore, vitamin K had a positive correlation with unsaturated iron-binding capacity (UIBC) (p=0.04), but not with hemoglobin levels. A deficiency of 25(OH)D correlates with heightened anemia severity in ESRD patients receiving hemodialysis. PTH and vitamin K levels did not directly influence on the severity of anemia. Additional longitudinal studies are advised to investigate the therapeutic effects of vitamin D correction in the therapy of anemia.

Keywords: anemia, vitamin D, vitamin K, parathyroid hormone, chronic kidney disease

INTRODUCTION

Anemia is a prevalent and devastating consequence of end-stage renal disease (ESRD), particularly in patients receiving continuous hemodialysis[1-3]. The gradual decline in kidney function results in diminished erythropoietin production and a range of metabolic, endocrine, and inflammatory alterations that negatively impact red blood cell formation and longevity[4-6]. Consequently, anemia in ESRD is linked to reduced quality of life, elevated cardiovascular risk, and increased mortality[7-9]. Recent investigations have emphasized the significance of disrupted mineral metabolism, notably concerning vitamin D, vitamin K, and parathyroid hormone (PTH), as key contributors to anemia in ESRD. These variables, while historically associated with bone and mineral homeostasis, are now widely acknowledged for their potential impact on hematopoiesis and iron metabolism in chronic kidney disease (CKD)[10-13].

Vitamin D insufficiency is common in ESRD patients due to reduced renal production of its active form, 1,25-dihydroxyvitamin D (calcitriol). This deficit may hinder erythroid progenitor development, elevate inflammation, and diminish response to erythropoiesis-stimulating agents (ESAs)[14,15]. Moreover, vitamin D regulates immunological activity and hepcidin production, a crucial modulator of iron availability[16,17]. Likewise, vitamin K, a fat-soluble vitamin essential for the γ-carboxylation of several proteins, has been associated with erythropoiesis. Experimental models indicate that vitamin K may enhance red blood cell membrane integrity and regulate oxidative stress, although its precise role in anemia associated with CKD remains little explored[18,19]. PTH, which is increased in secondary hyperparathyroidism, is recognized for its detrimental impact on the bone marrow microenvironment. Elevated PTH might result in marrow fibrosis and inhibition of erythropoiesis, therefore

leading to ESA resistance and refractory anemia in patients undergoing dialysis[20-22]. Moreover, elevated PTH levels may enhance cytokine production and disrupt iron metabolism, both of which intensify the severity of anemia[23]. Anemia continues to be a persistent and intricate difficulty in the care of ESRD patients receiving hemodialysis. Studying how vitamins D, K, and the PTH hormone contribute to anemia could open up new possibilities for better diagnosis, prognosis, and developing treatments. Incorporating these markers into standard clinical assessments may enhance personalized anemia care and facilitate future therapeutic approaches aimed at mineral metabolism and endocrine equilibrium. Additional study is necessary to confirm these relationships and integrate them into clinical guidelines, particularly in emerging healthcare environments. Despite the documentation of these correlations in numerous research, data about Middle Eastern populations—especially Iraqi hemodialysis patients—are limited.

This study is to evaluate the correlation between vitamin D, vitamin K, and PTH levels and the severity of anemia in patients with ESRD having regular hemodialysis. Comprehending these connections may provide novel insights into anemia care beyond traditional iron and ESA treatments. This study aimed to assess the impact of vitamin D, vitamin K, and PTH levels on the severity of anemia in patients with ESRD receiving maintenance hemodialysis at Hamida Al-Masfah Dialysis Center, Al-Imamain Al-Kadhimain Teaching Hospital, Baghdad.

METHODOLOGY

Study design and setting

This cross-sectional, prospective study was conducted from November 1, 2023, to April 20, 2024, at the Hamida Al-Masfah Dialysis Center located in Al-Imamain Al-Kadhimain Teaching Hospital, Baghdad, Iraq. One hundred adult patients with confirmed ESRD undergoing maintenance hemodialysis were included. All participants were 18 years of age or older and had received regular hemodialysis for at least three months.

Inclusion and exclusion criteria

The inclusion criteria were adult patients with ESRD on chronic hemodialysis for at least three months and administered erythropoiesis-stimulating drugs (ESAs) for anemia management. Patients were excluded if they had ongoing infections, malignancies, iron deficiency anemia (defined as serum ferritin <100 ng/mL and transferrin saturation <20%), recent significant hemorrhages (within the last three months), or inadequate clinical or laboratory data.

Data collection

Demographic and clinical data were obtained via structured interviews and medical records, encompassing age, sex, occupation, family history, smoking status, etiology of kidney failure, duration of ESRD, dialysis regimen and duration, erythropoiesis-stimulating agent (ESA) dosage and frequency, comorbidities, and history of kidney transplantation.

Laboratory assessments

Approximately 10 mL of venous blood was extracted from each patient prior to the dialysis session. The blood was allocated into suitable tubes for hematological and biochemical analyses. Hemoglobin (Hb) concentrations were quantified utilizing a CBC analyzer (Phoenix, Japan). Serum samples were processed and preserved at −80°C for subsequent analysis. PTH was quantified utilizing ELISA kits (Cloud Clone Corp., USA), employing a competitive inhibition enzyme immunoassay technique. Vitamin D was evaluated using two parameters: total vitamin D3 and 25-hydroxyvitamin D3, employing ELISA kits from Cloud Clone Corp. (USA) and Elabscience (China), respectively. Serum vitamin K concentrations were assessed using ELISA utilizing kits from Cloud Clone Corp. (USA). Serum calcium, phosphorus, albumin, creatinine, and eGFR were quantified via spectrophotometric techniques with an automated chemistry analyzer (Cobas Integra 400 Plus, Roche Diagnostics).

Grouping criteria

Patients were categorized into two groups according to hemoglobin levels: severe anemia (Hb <8 g/dL) and non-severe anemia (Hb ≥8 g/dL). Furthermore, participants were classified based on PTH levels into two subgroups: <150 pg/mL and 150–600 pg/mL. Analyses were stratified by gender to assess any sex-based variations.

Ethical considerations

Ethical approval for the study was obtained from the Institutional Review Board (IRB) of the College of Medicine, Al-Nahrain University on 18-07-2023, with the decision number 20230380. All participants were apprised of the study's nature and objectives, and verbal informed consent was secured prior to enrollment. All procedures adhered to the ethical standards established in the Declaration of Helsinki.

Statistical analysis

Statistical analysis was performed with IBM SPSS Statistics version 26.0. The Shapiro–Wilk test was employed to evaluate the normality of the data which revealed that Hematological tests, routine biochemical test and demographic categories were normally distributed, whereas Vitamin D, Vitamin K, and PTH were non-normally distributed. Continuous variables were presented as mean ± standard deviation (SD) and/or median and interquartile range (IQR), as applicable. Categorical data were displayed as frequencies and percentages. Comparisons of anemia groups and PTH categories were conducted utilizing one-way ANOVA or Kruskal-Wallis tests for continuous variables, and chi-square (χ^2) or Fisher's exact tests for categorical variables[24]. Pearson and Spearman correlation analyses were performed to examine the relationships between vitamin D, vitamin K, PTH levels, and clinical/hematological markers. A p-value less than 0.05 was deemed statistically significant[25,26].

RESULTS AND DISCUSSION

This study included 100 adult patients undergoing hemodialysis. Patients were categorized according to the severity of anemia into three groups: mild (n=15), moderate (n=39), and severe (n=46). Table 3-1 illustrates the distribution of demographic features across different groupings. No significant variations were seen in age, sex, occupation, weight, height, Body mass index (BMI), smoking status, alcohol use, or estimated glomerular filtration rate (eGFR) among the anemia severity groups ($p>0.05$ for all variables).

Table 1 delineates the correlation between clinical features and the degree of anemia. The status of kidney transplant, length of ESRD, duration and frequency of hemodialysis (HD), duration of erythropoiesis-stimulating agents (ESA), and frequency of ESA exhibited no significant differences across the anemic groups, with the exception of ESA frequency, which was substantially correlated ($p=0.02$).

Table 1. Association of demographic characteristics with the severity of anemia

Variables	Mild (n=15)	Moderate (n=39)	Severe (n=46)	p-value
Cause of CKD				
Diabetes	3(20%)	5(12.82%)	7(15.22%)	
Hypertension	2(13.33%)	9(23.08%)	6(13.04%)	
DM+HTN	3(20%)	9(23.08%)	15(32.61%)	
ADPKD	1(6.67%)	1(2.56%)	7(15.22%)	0.32
HTN + analgesic	0(0%)	4(10.26%)	2(4.35%)	
Neurogenic B.	1(6.67%)	4(20.26%)	2(4.35%)	
Renal atrophy	0(0%)	2(5.13%)	3(6.52%)	
Others	5(33.33%)	5(15.82%)	4(8.7%)	
Kidney transplant				
No	13(86.67%)	36(92.31%)	44(95.56%)	0.48
Yes	2(13.33%)	3(7.69%)	2(4.35%)	
ESRD duration				
Mean ± SD	7.46 ± 7.90	6.15 ± 5.0	7.26 ± 9.27	0.90
Median	4.00	4.0	5.00	
Range	2.00-33.00	1.00-24.00	0.50-59.00	
HD duration, yrs				
Mean ± SD	3.5 ± 3.05	4.00 ± 2.76	3.47 ± 2.57	0.47
Median	3.00	3.00	2.75	
Range	0.30-12.00	0.60-11.00	0.25-12.00	
HD frequency/wks				
Once	0(0%)	1(2.56%)	0(0%)	
Twice	3(20%)	4(10.26%)	5(10.87%)	0.62
Thrice	12(80%)	34(87.18%)	41(89.13%)	
ESA duration				
Mean ± SD	3.00 ± 2.51	4.78 ± 3.41	3.7 ± 2.73	0.08
Median	2.00	3.75	3.00	
Range	0.30-9.00	0.70-15.00	0.50-12.00	
ESA frequency				
Once	7(46.67%)	27(69.23%)	38(82.61%)	0.02*
Twice	3(20%)	9(23.08%)	9(19.57%)	
Thrice	5(33.33%)	3(7.69%)	3(6.52%)	

* Significant at $p<0.05$

Table 2 presents an analysis of hematological parameters, including ferritin, UIBC, iron, TIBC, transferrin, and transferrin saturation. Transferrin saturation (p=0.01), prothrombin time (PT, p=0.02), and international normalized ratio (INR, p=0.02) exhibited significant correlations with the severity of anemia.

Table 2. Association of hematological parameters with the severity of anemia

Variables	Mild (n=15)	Moderate (n= 39)	Severe (n= 46)	p-value
Ferritin Mean ± SD Range	 555.80 ± 319.10 114-1200	 539.10 ± 279.00 134-1200	 461.80 ± 280.10 44-1200	 0.36
UIBC Mean ± SD Range	 184.00 ± 85.90 40-310	 177.50 ± 63.50 28-303	 159.10 ± 78.30 34-355	 0.38
Iron Mean ± SD Range	 70.80 ± 33.30 31.8-175	 78.30 ± 43.60 31-275	 82.10 ± 26.60 30-174	 0.56
TIBC Mean ± SD Range	 244.00 ± 77.50 114-363	 253.80 ± 59.80 96-381	 241.20 ± 68.80 112-425	 0.68
Transferrin Mean ± SD Range	 36.8 ± 356.600 12.70-152.20	 36.0 ± 43.000 12.20-286.50	 38.40 ± 23.80 14.50-155.40	 0.95
Transferrin saturation, % Mean ± SD Range	 43.20 ± 8.80[a] 22-57	 49.40 ± 9.90[ab] 32-76	 53.20 ± 12.80[b] 26-87	 0.01*
PT Mean ± SD Range	 16.30 ± 2.40[a] 13.9-23.7	 15.10 ± 1.50[b] 12.4-18.8	 14.80 ± 1.90[b] 11.8-21	 0.02*
INR Mean ± SD Range	 1.50 ± 0.23[a] 1.24-2.20	 1.40 ± 0.13[b] 1.10-1.70	 1.33 ± 0.18[b] 1.05-1.90	 0.02*

* Significant at $p<0.05$

The biochemical characteristics are displayed in Table 3. Vitamin D levels were markedly elevated in the moderate and severe anemic cohorts relative to the mild group ($p=0.02$). Other biochemical indicators, such as calcium, phosphorus, creatinine, albumin, 25(OH) vitamin D, vitamin K, and PHT, exhibited no significant variations between groups ($p>0.05$).

Table 3. Association of biochemical parameters with the severity of anemia

Variables	Mild (n=15)	Moderate (n= 39)	Severe (n= 46)	p-value
Calcium Mean ± SD Range	 8.71 ± 0.86 6.80-10.10	 8.80 ± 0.79 6.80-10.72	 8.74 ± 1.08 3.60-11.00	 0.95
Phosphorus Mean ± SD Range	 5.13 ± 1.75 2.80-9.00	 4.81 ± 1.41 1.81-7.60	 5.10 ± 1.70 2.80-13.70	 0.67
Creatinine Mean ± SD Range	 7.35 ± 2.13 3.90-11.70	 7.77 ± 2.43 2.70-12.40	 8.12 ± 3.24 2.80-19.30	 0.63
Albumin Mean±SD Range	 3.89 ± 0.59 2.35-4.80	 4.13 ± 1.124 2.94-9.40	 4.14 ± 0.86 3.20-7.90	 0.68
Vitamin D Mean ± SD Range	 54.70 ± 27.57[a] 6.54-89.48	 70.00 ± 18.35[b] 38.48-108.58	 69.95 ± 16.71[b] 37.93-102.48	 0.02*
25(OH) vitamin D Mean ± SD Range	 20.95 ± 4.87 12.21-28.97	 21.03 ± 5.04 12.24-30.75	 21.86 ± 4.71 12.3-32.06	 0.68
Vitamin K Mean ± SD Range	 983.19 ± 288.63 277.90-1427.20	 1010.93 ± 282.70 389.10-1937.20	 970.68 ± 335.00 149.95-1968.70	 0.66
PHT Mean ± SD Range	 115.16 ± 28.45 90.55-192.84	 105.23 ± 13.61 62.57 ± 128.88	 105.70 ± 12.16 71.80 ± 131.04	 0.11

* Significant at $p<0.05$

Patients were categorized based on PTH levels into two groups: those with suppressed PTH (<150 pg/mL) and those within the desired range (150–600 pg/mL). Table 4 displays the clinical aspects associated with PTH levels. The duration of HD (p=0.04) and ESA (p=0.04) was considerably prolonged in the target PTH group. Phosphorus levels were significantly increased in patients with low PTH (p=0.04), as demonstrated in Table 5.

Table 4. Association of clinical characteristics with PTH level

Variables	PTH (<150 pg/ml) (n=27)	PTH (150-600 pg/ml) (n=73)	p-value
Cause of CKD			
Diabetes	3(11.11%)	12(16.44%)	
Hypertension	4(14.81%)	13(17.81%)	
DM+HTN	9(33.33%)	18(24.66%)	
ADPKD	2(7.41%)	7(9.59%)	0.95
HTN + analgesic	1(3.70%)	5(6.85%)	
Neurogenic B.	2(7.40%)	5(6.85%)	
Renal atrophy	1(3.70%)	4(5.48%	
Others	5(18.52%)	9(12.33%)	
Kidney transplant			
No	27(100%)	66(90.41%)	0.10
Yes	0(0%)	7(9.59%)	
ESRD duration			
Mean ± SD	4.94 ± 4.23	7.57 ± 8.45	0.05*
Median	3.50	5.00	
Range	1.00-19	0.50-59.00	
HD duration, yrs			
Mean ± SD	3.06 ± 2.62	3.95 ± 2.72	0.04*
Median	2.00	3.50	
Range	0.50-10.00	0.25-12.00	
HD frequency, wks			
Once	0(0%)	1(1.37%)	
Twice	4(14.81%)	8(10.96%)	0.73
Thrice	23(85.19%)	64(87.67%)	
ESA duration			
Mean ± SD	3.36 ± 2.97	4.25 ± 3.03	
Median	2.00	3.00	0.04*
Range	0.50-10.00	0.30-15	
ESA frequency, wks			
Once	21(77.78%)	51(96.86%)	0.37
Twice	5(18.52%)	12(16.44%)	
Thrice	1(3.70%)	10(13.70%)	

* Significant at $p<0.05$

Table 5. Association of biochemical parameters with PTH level

Variables	PTH (<150 pg/ml) (n=27)	PTH (150-600 pg/ml) (n=73)	p-value
Calcium Mean ± SD Range	 8.82 ± 1.41 3.60-11.00	 8.74 ± 0.70 6.80-10.30	 0.70
Phosphorus Mean ± SD Range	 5.54 ± 2.31 2.90-13.70	 4.79 ± 1.27 1.81-7.70	 0.04*
Creatinine Mean ± SD Range	 8.05 ± 3.65 2.70-19.30	 7.81 ± 2.42 3.2-18.00	 0.71
Albumin Mean ± SD Range	 4.06 ± 0.87 2.35-7.70	 4.11 ± 1.04 3.17-9.40	 0.83
Vitamin D Mean ± SD Range	 70.68 ± 16.58 51.13-102.48	 66.58 ± 20.91 6.54-108.58	 0.36
25(OH) vit D Mean ± SD Range	 19.56 ± 5.25 12.21-29.93	 22.08 ± 4.52 12.3-32.06	 0.03*
Vitamin K Mean ± SD Range	 998.60 ± 231.80 633.30-1850.20	 995.10 ± 332.00 150.00-19768.70	 0.96

* Significant at $p<0.05$

Table 6 illustrates the hematological parameters by PTH status, showing no statistically significant differences in hemoglobin, iron indices, PT, or INR ($p>0.05$ for all).

Table 6. Association of hematological parameters with PTH level

Variables	PTH (<150 pg/ml) (n= 27)	PTH (150-600 pg/ml) (n=73)	p-value
Hb, g/dl Mean ± SD Range	 9.73 ± 1.76 5.8-13.10	 9.83 ± 1.57 6.80-14.80	0.78
Ferritin Mean ± SD Range	 454.9 ± 261.20 64-1200	 525.00-292.76 44-1200	0.28
UIBC Mean ± SD Range	 163.49 ± 80.00 38-355	 172.38 ± 72.18 28.33	0.60
Iron Mean ± SD Range	 81.39 ± 34.00 40-174	 78.00 ± 35.53 31-275	0.67
TIBC Mean ± SD Range	 246.15 ± 71.31 112-425	 246.64 ± 66.00 96-381	0.97
Transferrin Mean ± SD Range	 37.71 ± 27.95 13.61-155.36	 37.02 ± 36.02 12.23-286.46	0.93
Transferrin, % Mean ± SD Range	 46.89 ± 9.05 22-66	 51.42 ± 12.26 26-87	0.08
PT Mean ± SD Range	 16.5 ± 2.01 13.10-23.70	 14.95 ± 1.84 11.8-021	0.13
INR Mean ± SD Range	 1.40 ± 0.19 1.17-2.17	 1.34 ± 0.17 1.05-1.90	0.14

Anemia is a common and complex consequence in individuals with ESRD, frequently arising from many factors such as diminished erythropoietin production, persistent inflammation, and dietary deficits [6]. Our study evaluated the severity of anemia in 100 hemodialysis patients and its correlation with diverse clinical, biochemical, hematological, and bone-derived indicators.

In this cohort, 46% of patients were categorized as having severe anemia, 39% as having moderate anemia, and merely 15% as having mild anemia. Demographic parameters, including age, sex, BMI, smoking status, and eGFR, exhibited no statistically significant correlation with anemia severity, aligning with prior research indicating that demographic variables frequently lack predictive value regarding anemia severity in dialysis populations. The frequency of ESA showed a significant correlation with the severity of anemia (p=0.02). The elevated frequency of ESA in more anemic patients likely

indicates a therapeutic response rather than a causal relationship, as also noted in the study by Locatelli et al[27].

Hematological measures, including transferrin saturation, PT, and INR, exhibited significant correlations with anemia severity (p=0.01, 0.02, and 0.02, respectively). The noted elevation in PT and INR among mildly anemic patients may indicate potential coagulopathy or liver dysfunction, necessitating additional examination. These findings correspond with those of Brugnara[28], who underscored the significance of iron management and coagulation parameters in anemia associated with ESRD. Patients with moderate and severe anemia had significantly elevated vitamin D levels (p=0.02), although no significant variations were observed in 25(OH) vitamin D or vitamin K levels. Notably, while 25(OH)D levels showed no significant variation across anemia groups, patients exhibiting PTH levels within the target range (150–600 pg/mL) demonstrated significantly elevated 25(OH)D levels (p=0.03), suggesting a potential inverse correlation between vitamin D status and secondary hyperparathyroidism, as previously articulated by Levin et al[29].

No notable variations were seen in hemoglobin, iron indices, or coagulation parameters between the two PTH groups, suggesting that PTH status may affect bone metabolism more than hematopoiesis directly, unless accompanied by severe problems. This is in keeping with studies from Owda et al. and Hayati et al., where PTH suppression did not correlate substantially with hemoglobin levels[20,21]. These findings suggest the efficacy of integrating vitamin status with conventional hematological evaluations to enhance anemia risk stratification and management in hemodialysis patients. Frequent evaluation of PTH, osteocalcin, and inflammatory markers may provide early indications of underlying mineral bone problems that exacerbate anemia severity.

In conclusion, this study revealed a strong correlation between diminished 25-hydroxyvitamin D (25(OH)D) levels and heightened anemia severity in individuals with ESRD receiving hemodialysis. Conversely, PTH and vitamin K levels did not exhibit a direct association with hemoglobin concentration. Furthermore, 25(OH)D shown an inverse correlation with PTH levels, whereas vitamin K showed a positive association with UIBC but not with the degree of anemia. The data indicate that vitamin D level may significantly influence erythropoiesis in hemodialysis patients, but PTH and vitamin K may exert indirect effects via their impact on mineral and bone metabolism. Regular monitoring and rectification of vitamin D deficiency may enhance anemia care in this demographic.

Current findings suggest the routine assessment of 25-hydroxyvitamin D (25(OH)D) levels in patients with ESRD receiving hemodialysis, especially in cases of severe anemia. Vitamin D supplementation may act as an adjunctive approach in the management of anemia for patients with confirmed insufficiency. Despite the lack of a direct correlation between PTH and vitamin K with anemia severity, their assessment is crucial for the evaluation of mineral and bone metabolism. Additional longitudinal and interventional investigations are necessary to validate the therapeutic advantages of rectifying vitamin D deficiency on anemic outcomes.

STATEMENT OF ETHICS

Ethical approval for the study was obtained from the Institutional Review Board (IRB) of the College of Medicine, Al-Nahrain University on 18-07-2023, with the decision number 20230380. All participants were apprised of the study's nature and objectives, and verbal informed consent was secured prior to enrollment. All procedures adhered to the ethical standards established in the Declaration of Helsinki.

CONFLICT OF INTEREST STATEMENT

The authors have no conflicts of interest to declare.

AUTHOR CONTRIBUTIONS

Design and planning, RJM, AS; data collection, SLA, AG; data analysis, SLA, RJM; literature search and writing, SLA, RJM; supervision, RJM, AS; editing and proof reading, RJM, AS.

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