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ASSOCIATION BETWEEN NUTRITIONAL STATUS AND METABOLIC ACIDOSIS AMONG PATIENTS UNDERGOING MAINTENANCE HAEMODIALYSIS

Muhammad Sheharyar Khan[1], Mohammad Faizan Riaz[2], Najam ul Sahar[3], Adil Manzoor[4], Ehsan Elahi[5], Kinza Karim[6]

[1,2,4,5,6]Department of Nephrology, Pakistan Kidney and Liver Institute & Research Center (PKLI&RC), Lahore, Pakistan.
[3]Department of Histopathology, Gulab Devi Hospital, Lahore, Pakistan
*Corresponding Author: Dr. Muhammad Sheharyar Khan, Email: sheharyar.khan45@gmail.com

ABSTRACT

Objective: To determine the association between body mass index (BMI) and metabolic acidosis among patients with end-stage kidney disease undergoing maintenance hemodialysis.

Methods: This cross-sectional study was conducted in the Department of Nephrology, a tertiary care hospital in Lahore, Pakistan, from March 2026 to June 2026. A total of 196 adults receiving maintenance hemodialysis were enrolled by consecutive sampling. Metabolic acidosis was defined as pre-dialysis serum bicarbonate <22 mEq/L. BMI was classified according to World Health Organization criteria. Associations between BMI and metabolic acidosis were evaluated using chi-square test and multivariable logistic regression after adjustment for age, sex, diabetes mellitus, dialysis duration, serum albumin, and dialysis frequency.

Results: Of 196 patients (mean age 48.9±12.9 years; 59.7% male), 129 (65.8%) had metabolic acidosis. Patients with metabolic acidosis had a significantly lower mean BMI than those without (20.53±1.94 vs. 24.85±2.67 kg/m², p<0.001). Metabolic acidosis was most prevalent among underweight (79.5%) and normal-weight (75.6%) patients and least frequent among overweight/obese patients (44.8%). After adjustment for potential confounders, underweight (adjusted OR 4.10, 95% CI 1.55–10.86) and normal BMI (adjusted OR 3.21, 95% CI 1.55–6.66) remained independently associated with metabolic acidosis.

Conclusion: Lower BMI is independently associated with metabolic acidosis in patients with end-stage kidney disease receiving maintenance hemodialysis. Routine nutritional assessment together with serum bicarbonate monitoring may help identify patients at increased risk.

KEYWORDS (MeSH): Body Mass Index; Metabolic Acidosis; Renal Dialysis; Renal Insufficiency, Chronic; Nutrition Assessment.

INTRODUCTION

Metabolic acidosis is a common metabolic complication among patients with end-stage kidney disease (ESKD) receiving maintenance hemodialysis. Although intermittent hemodialysis partially corrects acid-base imbalance, many patients continue to experience low pre-dialysis serum bicarbonate concentrations because endogenous acid production exceeds bicarbonate replacement between dialysis sessions. Persistent metabolic acidosis has been associated with protein-energy wasting, skeletal muscle catabolism, impaired nutritional status, reduced physical function, and adverse clinical outcomes. Current Kidney Disease Outcomes Quality Initiative (KDOQI) recommendations advise maintaining pre-dialysis serum bicarbonate concentrations of at least 22 mEq/L to minimize these complications.[1]

Nutritional assessment is an essential component of routine care in patients undergoing maintenance hemodialysis. Body mass index (BMI) remains one of the most practical and widely used anthropometric indicators of nutritional status because it is inexpensive, reproducible, and easily applicable in routine clinical practice. Although BMI does not differentiate lean body mass from adiposity and may be influenced by fluid status, it continues to be an important screening tool for identifying patients at risk of protein-energy wasting.[2]

Several biological mechanisms support an association between metabolic acidosis and poor nutritional status. Chronic acid retention stimulates muscle protein degradation, suppresses protein synthesis, increases amino acid oxidation, and contributes to progressive loss of lean body mass. Consequently, patients with lower BMI may be more susceptible to metabolic acidosis, while persistent acidosis may further aggravate nutritional decline, creating a vicious cycle.[3]

The burden of chronic kidney disease continues to rise worldwide, particularly in low- and middle-income countries. South Asia has one of the highest reported prevalences of chronic kidney disease, posing a major public health challenge.[4]. In Pakistan, recent studies have also demonstrated a substantial burden of chronic kidney disease, highlighting the growing need for improved dialysis care and nutritional monitoring in this population.[5]

Despite the biological plausibility of an association between nutritional status and metabolic acidosis, evidence among maintenance hemodialysis patients remains limited and inconsistent, particularly from South Asian populations. Therefore, this study was conducted to determine the association between body mass index and metabolic acidosis among patients undergoing maintenance hemodialysis at a tertiary care hospital in Lahore.

MATERIALS AND METHODS

This is an observational cross-sectional study conducted in the department of Nephrology/Hemodialysis Unit of a tertiary healthcare facility in Lahore, Pakistan. Ethical approval was obtained from the Institutional Review Board (Approval No. 00111012). Written informed consent was obtained from all participants before enrolment. Total of 196 adult patients between March 2026 and June 2026 were recruited undergoing maintenance hemodialysis using the consecutive sampling method. All adults >18 years old undergoing maintenance hemodialysis for at least three months were included. Patients with recent hospitalization in the past four weeks, presence of infection or inflammatory disease, liver decompensation, malignancy, pregnancy, severe edema or ascites affecting the estimation of body weight, and missing data were excluded.

Sample size was calculated using OpenEpi v3.01 with anticipated prevalence of 65%, 95% CI, 7% absolute precision, yielding n=179. After 10% non-response, final n=196. [10]

Data were collected prospectively during the period of enrolment by means of structured proforma. Demographic variables included age, gender, place of residence, and duration of hemodialysis, while the clinical variables included the comorbidities like diabetes mellitus and hypertension, hemodialysis vintage, and frequency of dialysis per week.

Blood samples were obtained before the start of a scheduled hemodialysis session and serum bicarbonate <22 mEq/L was defined as metabolic acidosis and ≥22 mEq/L were classified as no metabolic acidosis [11]. Dialysate bicarbonate concentration of 35 mEq/L is most frequently used prescription in our center,

Body mass index was calculated using the formula:

BMI = weight in kilograms / height in meters²

The number of obese patients was small, so overweight and obese patients were combined for inferential analysis as a higher-BMI category and used as reference in regression analysis.

Statistical analysis: Data were analyzed using SPSS and continuous variables were summarized as mean ±standard deviation and categorical variables were presented as frequencies and percentages.

Patients were divided into two groups based on the presence or absence of metabolic acidosis. Mean BMI was compared between groups using the independent sample t-test. The association between BMI categories and metabolic acidosis was assessed using the chi-square test or Fisher's exact test. A p-value of <0.05 was considered statistically significant. Potential confounding variables including age, sex, diabetes mellitus, dialysis duration, serum albumin, and dialysis frequency were adjusted for in multivariable logistic regression. Hence, analysis was done to evaluate the independent association between BMI and metabolic acidosis.

RESULTS

A total of 196 patients were included. Mean age was 48.9 ±12.9 years, and 117 patients (59.7%) were male. Metabolic acidosis (HCO3 <22) was present in 129 patients, prevalence 65.8%. Patients with metabolic acidosis had significantly lower mean BMI vs those without (20.53 ± 1.94 kg/m² vs. 24.85 ±2.67 kg/m²; p<0.001). By BMI category, metabolic acidosis was most frequent in underweight: 31/39 (79.5%), followed by normal weight: 68/90 (75.6%). Lowest prevalence was in overweight/obese: 30/67 (44.8%). Association was significant.

The prevalence of metabolic acidosis varied significantly across BMI categories. It was highest among underweight patients (79.5%), followed by those with normal BMI (75.6%), and lowest among overweight/obese patients (44.8%), demonstrating a statistically significant association between lower BMI and metabolic acidosis (Table 1).

In multivariable logistic regression analysis adjusted for age, sex, diabetes mellitus, dialysis duration, serum albumin, and dialysis frequency, both underweight BMI and normal BMI remained independently associated with metabolic acidosis compared with overweight/obese patients (Table 2).

Table 1. Association between BMI category and metabolic acidosis

BMI category	Total n=196	Metabolic acidosis present n=129	No metabolic acidosis n=67	Prevalence of metabolic acidosis	p-value
Underweight, <18.5 kg/m²	39 (19.9%)	31 (24.0%)	8 (11.9%)	79.5%	
Normal weight, 18.5–24.9 kg/m²	90 (45.9%)	68 (52.7%)	22 (32.8%)	75.6%	
Overweight/obese, ≥25 kg/m²	67 (34.2%)	30 (23.3%)	37 (55.2%)	44.8%	
Total	196 (100%)	129 (65.8%)	67 (34.2%)	65.8%	<0.001

Table 2. Binary logistic regression analysis for predictors of metabolic acidosis

Variable	Adjusted OR	95% CI	p-value
Age, per year increase	1.01	0.98–1.04	0.421
Male sex	1.14	0.58–2.24	0.701
Diabetes mellitus	1.08	0.52–2.23	0.839
Dialysis duration, per month increase	1.01	0.99–1.03	0.287
Serum albumin, per 1 g/dL increase	0.54	0.25–1.16	0.113
Normal BMI vs overweight/obese	3.21	1.55–6.66	0.002
Underweight BMI vs overweight/obese	4.10	1.55–10.86	0.005

Note: Dependent variable was presence of metabolic acidosis, defined as pre-dialysis serum bicarbonate <22 mEq/L. Model adjusted for age, sex, diabetes mellitus, dialysis duration, serum albumin and BMI category.

DISCUSSION

The present study demonstrated that 65.8% of patients receiving maintenance hemodialysis had metabolic acidosis, indicating that acid–base disturbances remain common despite regular dialysis. This prevalence is comparable to the 62.9% reported by Sajgure et al. among Indian maintenance hemodialysis patients [6] but considerably lower than the 94.7% observed by de Oliveira et al. in a Brazilian cohort.[12] These differences may be due to dialysis prescription, dialysate bicarbonate concentration, residual kidney function, dietary protein intake, and timing of predialysis bicarbonate measurement.

The principal finding of the present study was the significant inverse association between body mass index (BMI) and metabolic acidosis. Patients with metabolic acidosis had a significantly lower mean BMI than those without metabolic acidosis (20.53 ±1.94 vs. 24.85 ±2.67 kg/m²).

Furthermore, metabolic acidosis was most prevalent among underweight (79.5%) and normal-weight (75.6%) patients, whereas overweight/obese patients had the lowest prevalence (44.8%). After adjustment for age, sex, diabetes mellitus, dialysis duration, serum albumin, and dialysis frequency, both underweight (adjusted OR 4.10) and normal BMI (adjusted OR 3.21) remained independent predictors of metabolic acidosis. These findings support previous evidence suggesting that poor nutritional status is closely associated with acid–base imbalance in patients undergoing maintenance hemodialysis.[1-2]

Our findings are consistent with those of de Oliveira et al., who demonstrated that patients with metabolic acidosis had significantly lower anthropometric measurements and poorer nutritional indices than patients without metabolic acidosis.[12] Similarly, studies evaluating correction of metabolic acidosis have shown that improvement in serum bicarbonate levels is associated with better nutritional status, preservation of muscle mass, and reduced protein-energy wasting, suggesting that metabolic acidosis is not only a consequence of kidney failure but also an important contributor to malnutrition. [7,8]

Our findings are partially consistent with those reported by Al-Jubouri et al., who investigated the role of metabolic acidosis in malnutrition among patients receiving maintenance hemodialysis. They observed that malnutrition was present in 50% of patients with metabolic acidosis, whereas only 5.6% of patients undergoing adequate hemodialysis were malnourished compared with 71.4% of those receiving inadequate hemodialysis. Based on these findings, the authors concluded that inadequate hemodialysis, rather than metabolic acidosis, was the principal determinant of malnutrition. In contrast, our study demonstrated that lower BMI remained independently associated with metabolic acidosis even after adjustment for dialysis duration, dialysis frequency, and serum albumin, suggesting that metabolic acidosis may independently contribute to impaired nutritional status. The differences between the two studies may be attributed to variations in study design, nutritional assessment methods, evaluation of dialysis adequacy, patient characteristics, and statistical adjustment for potential confounding variables.

Collectively, these findings suggest that metabolic acidosis and inadequate hemodialysis are likely complementary, rather than mutually exclusive, contributors to poor nutritional status in patients undergoing maintenance hemodialysis [13].

The biological mechanisms underlying these observations are well established. Chronic metabolic acidosis stimulates skeletal muscle protein degradation through activation of the ubiquitin–proteasome pathway, suppresses protein synthesis, increases amino acid oxidation, and promotes insulin resistance and inflammation, ultimately resulting in protein-energy wasting and loss of lean body mass.[8,9] Recent reviews have reaffirmed that persistent metabolic acidosis contributes to poor nutritional status, reduced physical function, and adverse clinical outcomes in patients receiving maintenance dialysis.[9] Our study results suggested that patient with higher BMI had less metabolic acidosis and those with low BMI were more prone to metabolic acidosis which resulted in their protein degradation

Our findings differ from those reported by Kabiri Naeini et al.[14], who assessed nutritional status in 201 maintenance hemodialysis patients using the Modified Quantitative Subjective Global Assessment (MQ-SGA). They found a high prevalence of malnutrition (63.2%) and identified older age, longer dialysis duration, lower serum albumin, and lower serum creatinine as independent predictors of malnutrition, whereas BMI was not independently associated with nutritional status. In contrast, our study demonstrated that lower BMI remained independently associated with

metabolic acidosis after adjustment for age, dialysis duration, dialysis frequency, and serum albumin, suggesting that BMI may better reflect the nutritional consequences of metabolic acidosis than global nutritional status alone. The differences between the two studies may be explained by the use of different nutritional assessment tools (MQ-SGA versus BMI), distinct study objectives, and variations in patient characteristics and analytical models.

Similar to khalil et al.[15], our study highlights that malnutrition remains a common problem among patients receiving maintenance hemodialysis. However, while khalil et al. primarily described the burden and demographic determinants of malnutrition, our study further identified metabolic acidosis as an independent factor associated with lower BMI, emphasizing its potential role in the pathogenesis of malnutrition.

The findings of the present study have important clinical implications. BMI is an inexpensive, reproducible, and readily available anthropometric measure that can easily be incorporated into routine dialysis care. Although it does not distinguish lean body mass from adiposity and may be affected by fluid overload, patients with lower BMI appear to be at greater risk of metabolic acidosis and may benefit from closer nutritional surveillance, regular monitoring of serum bicarbonate, and timely interventions aimed at optimizing both nutritional status and acid–base balance.[2]

Limitations

This study has several limitations. First, its cross-sectional design precludes establishing a causal relationship between BMI and metabolic acidosis. Second, it was conducted at a single tertiary care center, which may limit the generalizability of the findings. Third, BMI was used as the primary indicator of nutritional status and does not differentiate lean body mass from adiposity. Finally, important variables such as residual kidney function, dietary protein intake, inflammatory markers, and dialysis adequacy were not evaluated and may have influenced the observed associations.

Recommendations

Routine monitoring of serum bicarbonate should be combined with regular nutritional assessment in patients receiving maintenance hemodialysis, particularly those with low BMI. Future multicentre prospective studies incorporating comprehensive nutritional and biochemical assessments are recommended to further clarify the relationship between nutritional status and metabolic acidosis.

CONCLUSION

Lower BMI was independently associated with metabolic acidosis among patients with end-stage kidney disease undergoing maintenance hemodialysis. Routine assessment of nutritional status together with monitoring of serum bicarbonate may facilitate early identification of high-risk patients and support timely interventions to improve clinical outcomes.

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