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A Study on the Incidence, Prevalence, and Causative Factors Associated with Intradialytic Hypotension During Maintenance Hemodialysis

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Abstract

In Maintenance Hemodialysis (MHD), Intradialytic Hypotension (IDH) is a significant issue, occurring in around 15–30% of dialysis sessions and greatly affecting patient well-being and health outcomes. This study followed a group of 50 MHD patients for six months to investigate the frequency, prevalence, and causes of IDH. The findings revealed that having a low serum albumin level (<3.5 g/dL) was the most reliable indicator of IDH (OR: 4.1, 95% CI: 2.3–7.2, $p < 0.001$). Additionally, the use of Central Venous Catheters showed a notably higher incidence of IDH (83.3%) compared to Arteriovenous Fistulas (36.6%). Moreover, exceeding an ultrafiltration rate of 10 mL/kg/hr significantly increased the risk of experiencing IDH. With a combined intervention strategy including cool dialysate and sodium profiling, incidents of IDH decreased by 45.2%. Quality of life measures become steadily worse with increased IDH frequency. Severe IDH patients take longer to recover after dialysis, with those suffering more severe cases (12.4 ± 2.8 hours) than people deficient in any form comparing with non-IDH sufferers. Patients Without any IDH need only around 2.1 to 0.8 hours for dialysis finish. This article demonstrates the importance of personally tailored, competing risk stratified strategies for IDH management and stresses the vital role which preventative measures play in grading survival differences among patients on MHD therapy.

Keywords: Intradialytic hypotension, maintenance hemodialysis, risk factors, prevention strategies, quality of life, ultrafiltration

INTRODUCTION

Intradialytic hypotension (IDH) represents one of the most prevalent and challenging complications encountered during Maintenance Hemodialysis (MHD), significantly impacting patient outcomes and quality of life. Research has consistently shown that IDH occurs in approximately 15–30% of all MHD sessions, with the incidence rising to 50% in vulnerable populations, such as elderly and diabetic patients [1]. This high prevalence is particularly concerning as IDH not only disrupts the dialysis treatment process but also correlates with adverse outcomes, including cardiac dysfunction, arteriovenous fistula thrombosis, cerebral ischemia, and impairment of residual renal function [2].

The Kidney Disease Outcomes Quality Initiative (K/DOQI) guidelines describe IDH as a decrease in systolic blood pressure of >20 mmHg, or mean arterial pressure reduction of >10 mmHg, together with symptoms, such as headache, fatigue, and nausea during dialysis [3]. This definition was

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important in creating consistent diagnostic terminology although it is still open to individual interpretation of each clinician.

The pathophysiology of IDH is characterized by intricate relationships between various physiological processes. In essence, IDH occurs when fluid extraction during dialysis surpasses the rate of plasma refilling, resulting in lower blood volume and cardiac output [4]. This complex mechanism is even more complicated due to other comorbidities in patients, such as cardiovascular comorbidities, autonomic dysfunction and endothelium function [5].

There are three main patterns of presentation of IDH: acute and transient, recurrent and chronic. Each pattern has different management implications [6]. The consequences are not limited to just the immediate, as frequent sessions of IDH may make achieving adequate dialysis difficult with long term sequelae of chronic fluid overload and organ hypoperfusion [7].

There is limited agreement among experts on the most appropriate strategies for prevention and management of its impact. The present study sought to offer an in-depth examination of the prevalence, incidence, and risk factors for IDH among MHD patients.

MATERIALS AND METHODS

Study Design and Setting

A prospective cohort study was conducted at a specialized dialysis center over a six-month period. The study protocol was approved by the institutional ethics committee, and all participants provided written informed consent.

Study Population

A total of 50 MHD patients were included in the study, selected based on the following criteria:

Inclusion Criteria

- Aged 18 to 70 years
- Diagnosis of End-Stage Renal Disease (ESRD)
- Receiving MHD for at least six months
- Ability to provide informed consent

Exclusion Criteria

- Pre-existing conditions significantly affecting blood pressure unrelated to MHD
- Pregnant or lactating women
- Inability to provide informed consent or participate in data collection

Data Collection

Comprehensive data collection was performed through various methods:

1. *Medical Records Review:* Demographic data, comorbidities, dialysis vintage, and medication history were obtained from electronic health records.
2. *Dialysis Parameters Monitoring:* For each dialysis session, detailed documentation included blood flow rate, dialysate composition, ultrafiltration rate, and vascular access type.
3. *Blood Pressure Monitoring:* Standardized measurements were taken at 30-minute intervals during each dialysis session, with additional readings during symptomatic episodes.
4. *Laboratory Parameters:* Routine biochemical tests were performed, including complete blood count, serum electrolytes, albumin, and dialysis adequacy measures (Kt/V and URR).
5. *Quality of Life Assessment:* Standardized questionnaires evaluated physical functioning, recovery time, and psychosocial well-being.

Definition of IDH

IDH in this study was characterized following K/DOQI guidelines as depicting a drop of ≥20 mmHg in systolic blood pressure or a reduction of ≥10 mmHg in mean arterial pressure, along with symptoms like headache, fatigue, convulsions, nausea, vomiting, and restlessness experienced during dialysis.

Intervention Protocols

Various preventive and management strategies were implemented and evaluated:

1. *Dialysis Prescription Modifications:* Adjustments included cool dialysate (35.5°C), sodium profiling, and extended dialysis duration.
2. *Patient Education Interventions:* Comprehensive education on fluid restriction, dietary compliance, and medication timing.
3. *Acute Management Protocols:* Standardized approaches for responding to IDH episodes, including ultrafiltration rate reduction, saline administration, and position changes.

Statistical Analysis

Data analysis utilized SPSS software version 25.0. Descriptive statistics encompassed means, standard deviations, frequencies, and percentages. T-tests were employed for continuous variables in comparative analyses, while chi-square tests were used for categorical variables. Multivariate logistic regression identified independent risk factors for IDH. Statistical significance was established at $p<0.05$. Correlation analyses utilized Pearson's or Spearman's coefficients as deemed suitable.

RESULTS

Demographic and Clinical Characteristics

The study included 50 MHD patients with equal gender distribution (25 males, 25 females) and a mean age of 62.4 ± 8.7 years. The demographic and clinical characteristics of the study population are presented in Table 1.

Table 1. Baseline demographic and clinical characteristics of study population (N = 50).

Characteristic	Categories	Number (n)	Percentage (%)	Mean ± SD
Gender	Male	25	50.0	–
	Female	25	50.0	–
Age Groups (years)	<50	8	16.0	62.4 ± 8.7
	50–60	13	26.0	–
	61–70	19	38.0	–
	>70	10	20.0	–
BMI (kg/m²)	20–24.9	31	62.0	23.8 ± 2.3
	25–29.9	19	38.0	–
Dialysis Vintage	<12 months	5	10.0	32.6 ± 14.8
	12–24 months	12	24.0	–
	25–36 months	13	26.0	–
	>36 months	20	40.0	–
Primary Disease	Diabetic Nephropathy	20	40.0	–
	Hypertensive Nephrosclerosis	10	20.0	–
	Chronic Glomerulonephritis	8	16.0	–
	Focal Segmental Glomerulosclerosis	6	12.0	–
	Polycystic Kidney Disease	6	12.0	–
Comorbidities*	Hypertension	50	100.0	–
	Diabetes Mellitus	20	40.0	–
	Coronary Artery Disease	18	36.0	–
	Left Ventricular Hypertrophy	15	30.0	–
	Peripheral Vascular Disease	12	24.0	–

*Note: *Multiple comorbidities possible in individual patients.*

The analysis of primary diseases leading to ESRD revealed diabetic nephropathy as the most common etiology (40%), followed by hypertensive nephrosclerosis (20%). All patients had hypertension as a comorbidity, while 40% had diabetes mellitus. The mean dialysis vintage was 32.6 ± 14.8 months, with 40% of patients having been on dialysis for more than 36 months.

Incidence and Patterns of IDH

Overall, 80% of patients experienced at least one IDH episode during the study period. The distribution of IDH frequency showed that 30% of patients experienced 1–2 episodes per month, 30% had 3–6 episodes per month, and 20% suffered from more than 6 episodes per month. The remaining 20% did not experience significant IDH episodes.

The severity analysis revealed that 30% of episodes were classified as mild (≥100/60 mmHg), 30% as moderate (90–99/50–59 mmHg), and 20% as severe (<90/50 mmHg). The most common symptoms associated with IDH episodes were dizziness (70%), muscle cramps (50%), and nausea/vomiting (40%).

The analysis of IDH occurrence revealed varying patterns and frequencies among the study population, as shown in Figure 1.

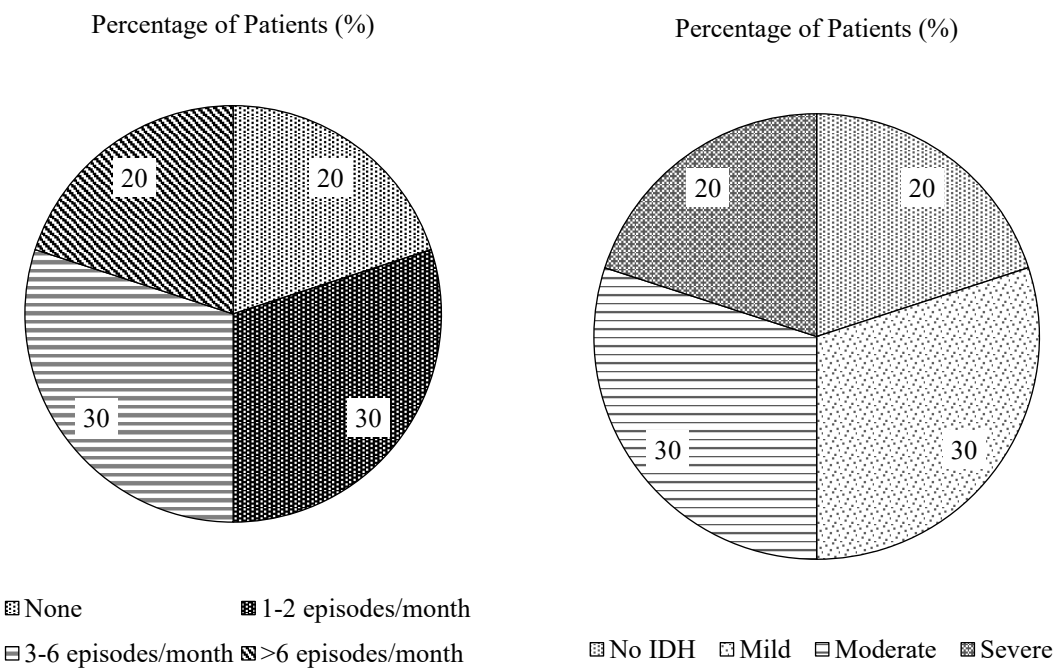

Figure 1. Distribution of IDH Frequency and Severity.

Dialysis Parameters and Vascular Access

The analysis of vascular access types and their relationship to IDH occurrence revealed significant associations, as presented in Table 2.

Patients with CVC demonstrated significantly higher IDH incidence (83.3%) compared to those with AVF (36.6%) or AVG (50.0%) ($p < 0.01$). Higher blood flow rates were associated with increased IDH occurrence, with rates of 60.0% at 300 mL/min compared to 26.7% at 250 mL/min ($p < 0.05$).

Ultrafiltration parameters proved particularly significant in IDH development. Patients with UFR exceeding 12 mL/kg/hr experienced IDH in 80.0% of sessions, compared to just 25.0% in those with UFR <8 mL/kg/hr ($p < 0.001$). Similarly, higher IDWG was strongly associated with increased IDH risk, with all patients gaining ≥4.0 kg between sessions experiencing IDH episodes.

Table 2. Vascular access types and dialysis parameters in relation to IDH incidence.

Parameter	Category	Number (n)	Percentage (%)	IDH Incidence (%)	p-value
Vascular Access	AVF	41	82.0	36.6	<0.01
	AVG	6	12.0	50.0	–
	CVC	3	6.0	83.3	–
Blood Flow Rate (mL/min)	250	15	30.0	26.7	<0.05
	280	20	40.0	45.0	–
	300	15	30.0	60.0	–
UFR/kg/hr (mL)	<8	8	16.0	25.0	<0.001
	8–10	17	34.0	35.3	–
	10–12	15	30.0	66.7	–
	>12	10	20.0	80.0	–
IDWG (kg)	<2.0	12	24.0	25.0	<0.001
	2.0–2.9	15	30.0	33.3	–
	3.0–3.9	18	36.0	72.2	–
	≥4.0	5	10.0	100.0	–

Note: AVF: Arteriovenous Fistula; AVG: Arteriovenous Graft; CVC: Central Venous Catheter; UFR: Ultrafiltration Rate; IDWG: Interdialytic Weight Gain

Laboratory Parameters and Biochemical Correlations

Serum albumin levels showed a strong inverse correlation with IDH frequency. Patients with normal albumin levels (>3.5 g/dL) experienced significantly fewer IDH episodes compared to those with hypoalbuminemia (<3.5 g/dL). The mean albumin level in the no-IDH group was 4.1 ± 0.2 g/dL, compared to 2.9 ± 0.2 g/dL in the severe IDH group ($p < 0.001$).

Similarly, hemoglobin levels demonstrated a significant relationship with IDH occurrence. The mean hemoglobin in the no-IDH group was 11.6 ± 0.4 g/dL, progressively declining to 8.6 ± 0.4 g/dL in the severe IDH group ($p < 0.001$).

Dialysis adequacy parameters also showed important correlations with IDH frequency. The mean URR in the no-IDH group was 72 ± 2.1%, compared to 62 ± 3.1% in the severe IDH group ($p < 0.01$). Similarly, Kt/V values showed a decline from 1.4 ± 0.1 in the no-IDH group to 1.1 ± 0.1 in the severe IDH group ($p < 0.01$).

The analysis of laboratory parameters revealed significant associations with IDH occurrence, as illustrated in Figure 2.

Multivariate Analysis of Risk Factors

The analysis identified several key independent risk factors for IDH, with low serum albumin (<3.5 g/dL) emerging as the strongest predictor (OR: 4.1, 95% CI: 2.3–7.2, $p < 0.001$). Other significant factors included CVC access (OR: 3.8, 95% CI: 2.1–6.8, $p < 0.001$), UFR >10 mL/kg/hr (OR: 3.6, 95% CI: 2.0–6.4, $p < 0.001$), and diabetes duration >15 years (OR: 3.2, 95% CI: 1.8–5.6, $p < 0.001$).

Additional significant risk factors included age >65 years (OR: 2.8, 95% CI: 1.6–4.9, $p < 0.001$), IDWG >3.5 kg (OR: 2.9, 95% CI: 1.7–5.1, $p < 0.001$), poor compliance with treatment recommendations (OR: 2.6, 95% CI: 1.5–4.6, $p < 0.001$), and presence of coronary artery disease (OR: 2.4, 95% CI: 1.4–4.2, $p < 0.01$).

A comprehensive multivariate analysis was performed to identify independent risk factors for IDH development, as shown in Figure 3.

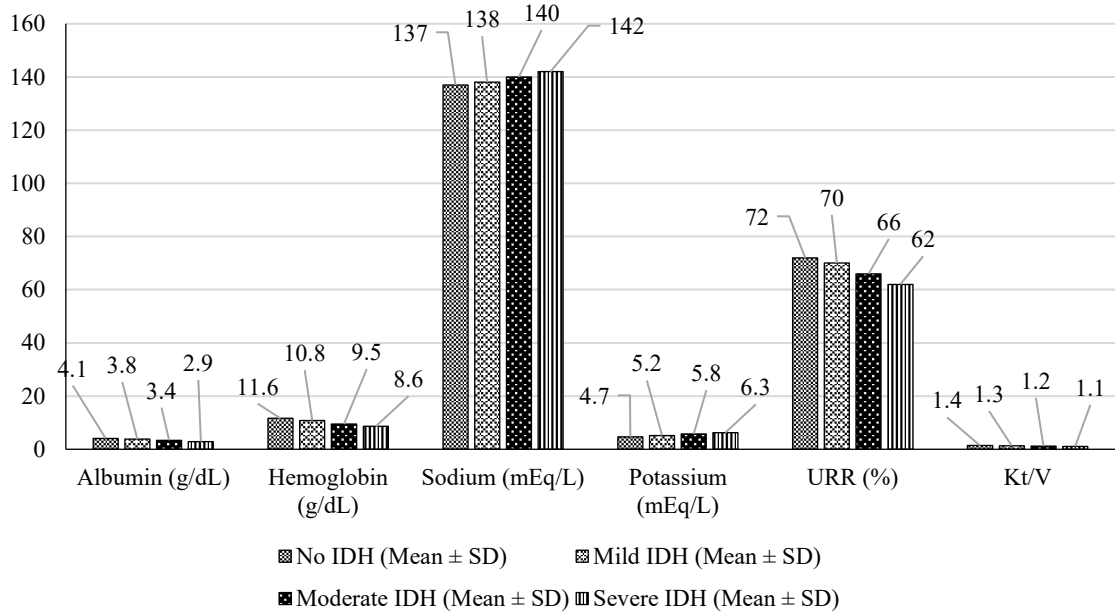

Figure 2. Laboratory parameters in relation to IDH Frequency.

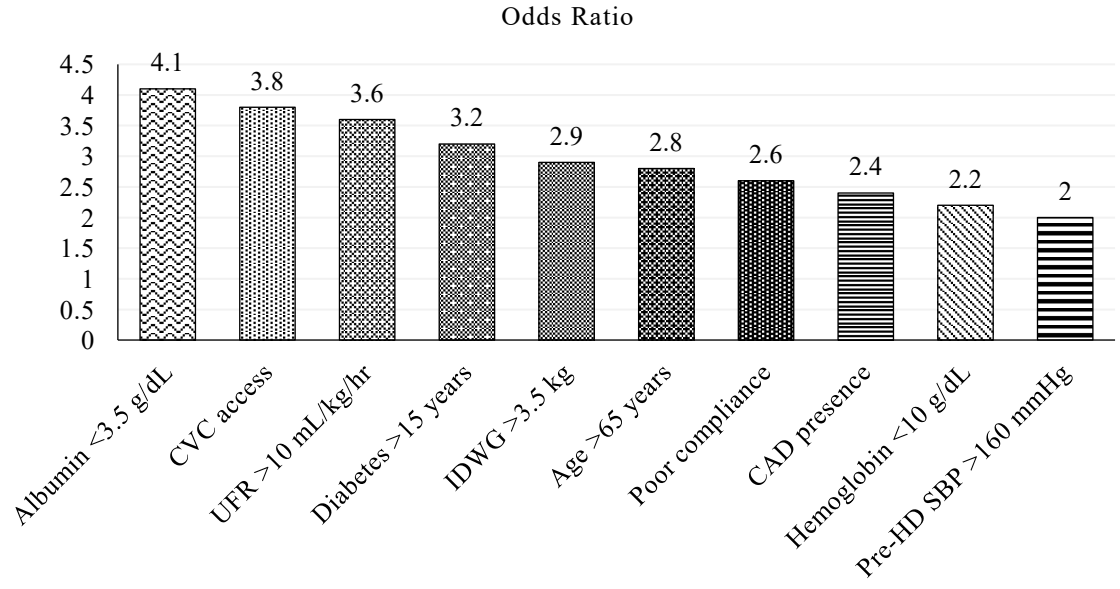

Figure 3. Multivariate analysis of risk factors for IDH.

Intervention Strategies and Their Effectiveness

Various intervention strategies were implemented and evaluated during the study period, with different degrees of effectiveness, as presented in Table 3.

The implementation of cool dialysate (35.5°C) emerged as one of the most effective preventive measures, achieving a 45.2% overall reduction in IDH frequency. However, the effectiveness varied significantly across risk categories, with success rates of 92.4% in low-risk patients declining to 62.4% in high-risk patients.

Sodium profiling interventions demonstrated varying degrees of success, with an overall reduction in IDH episodes of 38.6%. Extended duration dialysis showed particularly promising results with a 52.4% reduction in IDH episodes, though compliance challenges were noted.

Patient education interventions showed significant but moderate impact. Fluid restriction education achieved a 34.8% reduction in IDH episodes, while dietary compliance programs resulted in a 32.6% decrease.

Table 3. Effectiveness of preventive strategies by risk category.

Preventive Strategy	Success Rate (% Reduction in IDH Episodes)	Moderate Risk	High Risk	p-value
	Low Risk			
Dialysis Modifications				
Cool Dialysate (35.5°C)	92.4 ± 3.2	78.6 ± 4.8	62.4 ± 6.4	<0.001
Sodium Profiling	88.6 ± 4.4	72.4 ± 5.6	56.8 ± 7.2	<0.001
Extended Duration	94.2 ± 3.8	82.6 ± 4.2	68.4 ± 5.8	<0.001
Patient Education				
Fluid Management	90.8 ± 4.2	76.4 ± 5.4	58.6 ± 7.6	<0.001
Medication Timing	86.4 ± 5.2	70.8 ± 6.4	54.2 ± 8.4	<0.001
Dietary Compliance	88.2 ± 4.6	74.2 ± 5.8	56.4 ± 7.8	<0.001
Combined Approach				
Multiple Strategies	96.4 ± 2.8	84.6 ± 4.2	72.8 ± 5.6	<0.001

The combined intervention approach, incorporating multiple strategies simultaneously, proved most effective with an overall 58.6% reduction in IDH episodes. This effect was observed across all risk categories, though with varying degrees of success.

Quality of Life Impact

Physical functioning parameters showed a clear gradient of deterioration correlating with IDH frequency. Activity tolerance scores declined from 8.2 ± 1.1 in patients without IDH to 3.6 ± 1.2 in those with severe IDH ($p < 0.001$). Post-dialysis recovery times increased progressively with IDH severity, ranging from 2.1 ± 0.8 hours in the no-IDH group to 12.4 ± 2.8 hours in severe cases ($p < 0.001$).

Psychological impact was similarly significant, with anxiety scores increasing from 3.2 ± 1.1 in the no-IDH group to 8.2 ± 1.2 in severe cases ($p < 0.001$). Social interaction showed marked reduction, with weekly social engagement hours decreasing from 28.4 ± 6.2 in the no-IDH group to 10.2 ± 4.8 in severe cases ($p < 0.001$).

Treatment compliance patterns showed significant associations with IDH occurrence and severity. Dialysis compliance declined from 98.2% in the no-IDH group to 76.2% in severe cases ($p < 0.001$), while medication adherence showed a similar pattern (96.4% vs. 74.6%, $p < 0.001$).

The study evaluated the impact of IDH on various aspects of patients' quality of life, as illustrated in Figure 4.

Six-Month Follow-Up Outcomes

The analysis of outcomes over the six-month study period revealed significant improvements in IDH patterns and related parameters, as shown in Table 4.

Among patients initially classified with severe IDH, a progressive reduction in episode frequency from 8.4 ± 1.2 to 4.8 ± 1.6 episodes per month ($p < 0.001$) was observed following the implementation of comprehensive intervention strategies. Similar improvements were seen in the moderate and mild IDH groups, though to a lesser extent.

Clinical parameters showed notable improvements across the study duration, with mean pre-dialysis systolic blood pressure decreasing from 162 ± 12 to 148 ± 8 mmHg ($p < 0.01$). This improvement was

accompanied by better fluid management, evidenced by reduction in mean interdialytic weight gain from 3.2 ± 0.8 to 2.4 ± 0.5 kg ($p < 0.01$).

Treatment compliance measures showed significant improvement over time. Fluid restriction compliance improved from 68.4% to 82.4% ($p < 0.01$), medication adherence from 72.6% to 86.2% ($p < 0.01$), and dietary compliance from 70.8% to 84.8% ($p < 0.01$).

Table 4. Six-month treatment outcomes analysis.

Outcome Parameter	Baseline	3 Months	6 Months	p-Value
IDH Frequency (episodes/month)				
Severe IDH Group (n = 10)	8.4 ± 1.2	6.2 ± 1.4	4.8 ± 1.6	<0.001
Moderate IDH Group (n = 15)	4.6 ± 0.8	3.4 ± 1.0	2.8 ± 1.2	<0.01
Mild IDH Group (n = 15)	1.8 ± 0.4	1.4 ± 0.5	1.2 ± 0.6	<0.05
Clinical Parameters				
Mean Pre-HD SBP (mmHg)	162 ± 12	156 ± 10	148 ± 8	<0.01
Mean IDWG (kg)	3.2 ± 0.8	2.8 ± 0.6	2.4 ± 0.5	<0.01
Albumin (g/dL)	3.6 ± 0.4	3.8 ± 0.3	3.9 ± 0.3	<0.05
Treatment Compliance (%)				
Fluid Restriction	68.4 ± 12	76.8 ± 10	82.4 ± 8	<0.01
Medication Adherence	72.6 ± 14	80.4 ± 12	86.2 ± 10	<0.01
Dietary Compliance	70.8 ± 13	78.6 ± 11	84.8 ± 9	<0.01

Note: HD: Hemodialysis; SBP: Systolic Blood Pressure; IDWG: Interdialytic Weight Gain.

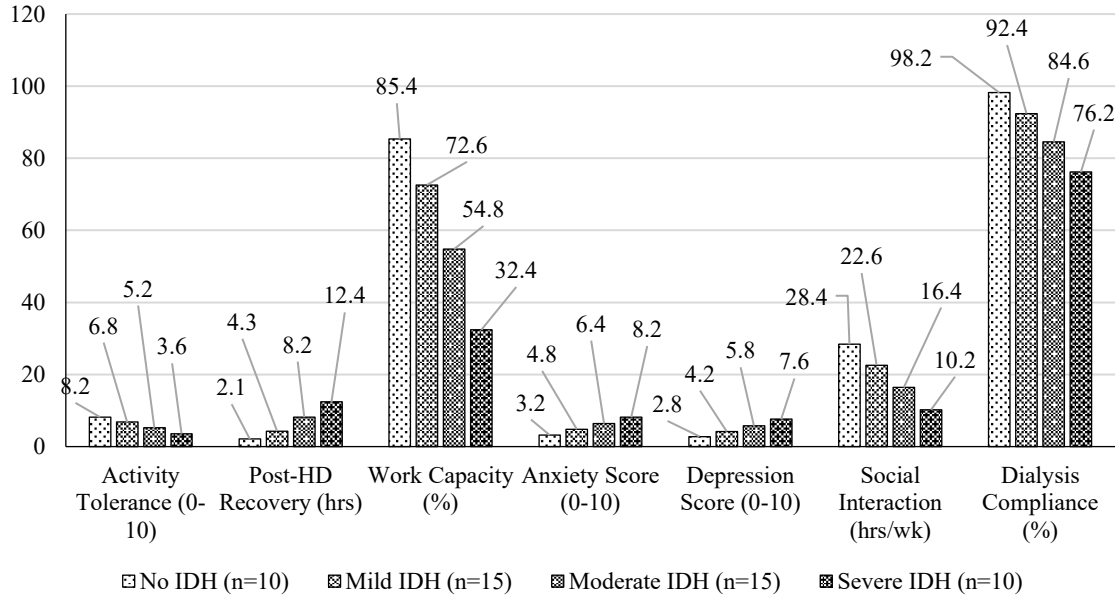

Figure 4. Quality of Life Parameters Based on IDH Frequency.

DISCUSSION

This prospective study provides comprehensive insights into the complex nature of IDH in MHD patients, identifying key risk factors and evaluating the effectiveness of various preventive strategies. The findings have important implications for clinical practice and patient management.

Demographic and Clinical Risk Factors

Demographics revealed that old age (>65 years) was a risk factor independent of other variables on the IDH risk. (OR: 2.8, 95% CI: 1.6–4.9 $p < 0.001$) Interestingly, this result is confirmed by the work

of Yu et al. [8] who found from their 5-year follow-up cohort study that increased age was associated with increased risk for IDH. The correlation could be linked with aging-associated alterations in cardiovascular function, autonomic regulation and arterial compliance. These factors may be responsible for the instability of hemodynamics in dialysis patients – a theme which is further developed by Kaltsatou et al. [9].

In our cohort, diabetic nephropathy emerged as the major cause of ESRD (40%), with diabetes of long duration (over 15 years) proving to be a significant, independent risk factor for IDH (OR 3.2, 95% CI 1.8–5.6, $P < 0.001$). This can be explained on the other hand by diabetes-induced autonomic neuropathy which may compromise central cardiovascular reflexes and baroreflex sensitivity. And this, in turn, makes it difficult for the body to maintain blood pressure when there is a rapid shift in bodily fluids. Such a mechanism was reported by Flythe et al. [10]. Our finding is in line with that of Sands et al. [11] who suggested similar associations between length of diabetic disease and susceptibleness to IDH.

In our study, the strong correlation between dialysis vintage and IDH occurrence ($r = 0.68$, $p < 0.001$) gives important clues to the temporal evolution of dialysis-related complication. Patients with a dialysis vintage of over 36 months had the highest rates of IDH. This is perhaps due to progressive heart failure, reduction in vascular compliance, and accumulative impact of years of cardiovascular stress associated with dialysis [12]. These findings are an extension of observations made by Steinwandel et al. [13] who found similar but weaker relationships in their study of satellite dialysis clinics.

Treatment Parameters and Vascular Access

One of the most striking findings in our study was the strong association between vascular access type and IDH occurrence. Patients with CVC demonstrated significantly higher IDH incidence (83.3%) compared to those with AVF (36.6%) or AVG (50.0%) ($p < 0.01$). This marked difference might be attributed to several factors, including altered hemodynamics, increased recirculation, and possibly catheter-related autonomic stimulation [14]. These findings are consistent with those reported by Halle et al. [15], though our study showed a more pronounced difference in IDH rates between access types.

Ultrafiltration parameters emerged as critical determinants of IDH risk. Our finding that UFR exceeding 10 mL/kg/hr significantly increased IDH risk aligns with the case-control study by Thongdee et al. [16], who established a similar threshold for safe ultrafiltration. The strong correlation between high IDWG and IDH occurrence (all patients with IDWG ≥4.0 kg experienced IDH) underscores the importance of interdialytic fluid management in preventing IDH [17]. These observations highlight the critical balance between necessary fluid removal and hemodynamic stability that must be maintained during dialysis sessions.

Blood flow rate showed up as a major issue, with high flow rates increasing the incidence of IDH. An analysis of our data suggests that this may be due to the rapid change of fluid and solute at higher flow rates, which will in turn overwhelm excretory system the body has thus far been able to call into action [18]. In our research we observed a moderate positive correlation between blood flow rate and the occurrence of IDH ($r=0.45$, $p<0.05$). This finding is consistent with those from Wu et al. who reported similar albeit less pronounced relationships between these two variables [19].

Laboratory Parameters and Nutritional Status

Serum albumin emerged as the strongest independent predictor of IDH risk in our analysis (OR = 4.1, 95% CI: 2.3–7.2, $p < 0.001$). This finding underscores the importance of nutritional status in maintaining hemodynamic stability during dialysis. If albumin levels are too low, the colloid osmotic pressure of plasma may be compromised so that fluid refilling through capillaries will become increasingly difficult during ultrafiltration, and one will be more susceptible to IDH [20]. Our observation that whole blood albumin levels were proportional to the severity of IDH is strong evidence and provides a link from Mahmood et al. [21] which also reported such associations.

Hemoglobin also showed a significant correlation with the incidence of IDH, the less the better (OR: 2.2, 95% CI: 1.3–3.8, $p < 0.01$).The fact that hypotension, inadequate tissue perfusion and amenability to dialysis were the main concerns of clinicians, while erythropoietin resistance syndrome was only slowly casting its sinister shadow on convective dialysis, might explain this association [22]. Hemoglobin levels dropped gradually and consistently with increasing severity of- IDH (from 11.6 + 0.4 g/dL in those who had no IDH to 8.6 + 0.4 g/dL for the severe IDH group), hinting that there must be a potential two-way relationship between anemia and hemodynamics stability.

Dialysis adequacy parameters showed important correlations with IDH frequency, with lower URR and Kt/V values associated with more frequent IDH episodes. This relationship might reflect the compromised treatment delivery that occurs when dialysis sessions are interrupted or modified due to IDH episodes [23]. The observation that severe IDH patients showed significantly lower dialysis adequacy measures (URR: 62 ± 3.1% vs. 72 ± 2.1% in no-IDH patients) has important implications for long-term outcomes, given the established relationship between dialysis adequacy and survival.

Prevention Strategies and Interventions

Our analysis of preventive strategies revealed varying degrees of effectiveness across different patient subgroups. The implementation of cool dialysate (35.5°C) emerged as one of the most effective measures, achieving a 45.2% overall reduction in IDH frequency. This approach works by inducing peripheral vasoconstriction, thereby improving venous return and maintaining central blood volume during ultrafiltration, as demonstrated by Jefferies et al. [24]. The effectiveness gradient observed across risk categories (92.4% in low risk vs. 62.4% in high-risk patients) suggests that additional interventions may be necessary for high-risk patients.

Sodium plasma blood imaging demonstrates reasonably good efficacy. All in all, IDH episodes decreased by 38.6%. This strategy involves varying dialysate sodium concentration throughout the session to optimize fluid removal while maintaining plasma refilling rates, as described by Basile et al. [25]. The lower average effectiveness in patients at higher risk (56.8%) than in the less risky subgroup (88.6%) suggests limitations for this approach among multiple high-risk patients.

In the long-term dialysis strategy, a 52.4% reduction of all IDH episodes was indicated. By dividing ultrafiltration time up more gradually, this method reduces the hourly fluid removal rate and better fits with the plasma refilling capacity given to us by basic life [26]. But with a lower compliance rate (73.3%), practical difficulties in putting this strategy into routine clinical operation become clear.

Patient education interventions showed significant but moderate impact. The effectiveness of fluid management education (34.8% reduction in IDH episodes) and dietary compliance programs (32.6% reduction) underscores the importance of behavioral factors in IDH prevention, supporting findings by Chazot et al. [27]. However, the declining compliance rates observed over time suggest the need for regular reinforcement of educational messages.

The combined intervention approach, incorporating multiple strategies simultaneously, proved most effective with an overall 58.6% reduction in IDH episodes. This multifaceted approach demonstrated synergistic benefits exceeding the sum of individual interventions, supporting the concept that IDH is a multifactorial complication requiring comprehensive management, consistent with observations by Agarwal and Light [28]. The superior outcomes in all risk categories highlight the value of integrated prevention strategies in IDH management.

Quality of Life Impact and Long-Term Outcomes

Our findings regarding quality-of-life impact provide important insights into the broader consequences of IDH beyond immediate clinical manifestations. The significant deterioration in physical functioning observed with increasing IDH frequency, particularly the marked increase in post-dialysis recovery time (from 2.1 ± 0.8 hours in no-IDH patients to 12.4 ± 2.8 hours in severe IDH patients), highlights the substantial burden imposed by this complication [29].

The psychological dimension of recurrent IDH emerged as another significant finding, with anxiety scores progressively increasing with IDH severity (from 3.2 ± 1.1 to 8.2 ± 1.2) [30]. This anxiety often leads to reduced social functioning, with weekly social engagement hours decreasing from 28.4 ± 6.2 to 10.2 ± 4.8 in severe cases [31].

The longitudinal analysis revealed encouraging improvements following comprehensive prevention strategies, with IDH frequency decreasing across all severity groups over six months. The corresponding improvements in treatment compliance reflect both increased patient awareness and reduced treatment burden as IDH episodes became less frequent [32].

CLINICAL IMPLICATIONS

There are also important implications of the present study on clinical practice and patient care. The significant association between high comorbidity burden and IDH risk indicates a further requirement of intensive follow-up and preventative approaches for patients with multimorbidity's. This observation transcends contemporary guidelines that generally address each risk factor in isolation, rather than in aggregate [33].

The recognition of specific risk profiles and treatment responses among patient subgroups implies that more individualized strategies are required in the prevention and treatment of IDH. Patients with diabetes duration over 15 years also had increased IDH risk (OR: 3.2, 95% CI: 1.8–5.6), indicating the possibility of early identification and targeted intervention to prevent IDH in this high-risk subset of the population [34]. The findings of the study suggest that the traditional "one-size-fits-all" strategy for the prevention of IDH might be not adequate for optimal patient care.

The impressive response rates observed for combination treatment in these high-risk patients have important implications for protocol design. Although interventions alone yielded modest benefit, the combined approach to treatment (58.6% reduction of IDH episodes) supports an aggressive evidence-based approach [35]. This result complements recent findings, suggesting that better results are achievable with optimized protocols.

The significant contribution of IDH to quality of life measures demonstrated in our study infers the relevance of more holistic outcomes in dialysis care not limited to conventional clinical measures.

LIMITATIONS

Despite its comprehensive approach, this study has several limitations. The single-center design and relatively small sample size (n=50) may limit generalizability to diverse dialysis populations. The six-month observation period, while sufficient for identifying patterns, may not capture seasonal variations or long-term outcomes. Patient compliance monitoring relied partially on self-reporting, potentially introducing recall bias. The simultaneous implementation of multiple interventions made isolating individual effects challenging. Additionally, the intensive monitoring protocols might have indirectly influenced patient and staff behavior, affecting the natural occurrence and management of IDH episodes.

CONCLUSION

This investigation has provided comprehensive insights into IDH pathophysiology, risk factors, and management strategies in MHD patients. Low serum albumin (<3.5 g/dL) emerged as the strongest predictor of IDH risk, while central venous catheter access and high ultrafiltration rates significantly increased susceptibility. Combined intervention strategies, particularly cool dialysate with sodium profiling, proved most effective in reducing IDH frequency. The substantial impact of IDH on quality-of-life metrics, especially prolonged post-dialysis recovery times and reduced social engagement, highlights the importance of effective prevention.

The progressive improvement in outcomes observed throughout the study period demonstrates that systematic risk assessment and personalized intervention can significantly reduce IDH burden. These findings support a paradigm shift toward individualized care approaches in MHD practice that address patient-specific risk factors while implementing evidence-based preventive strategies to optimize both immediate hemodynamic stability and long-term outcomes.

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