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# Intradialytic Hypertension and the Impact of Reduced Dialysate Sodium: A Prospective Observational Study

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## ABSTRACT

***Background:*** *Chronic kidney disease (CKD) is a progressive disorder with high morbidity and mortality, often advancing to end-stage renal disease (ESRD) requiring dialysis or transplantation. Intradialytic hypertension (IDH), defined as a paradoxical rise in blood pressure during hemodialysis, is an under-recognized complication that worsens patient outcomes. Understanding its prevalence and associated risk factors is essential to improving dialysis care and prognosis.*

***Aim:*** *This study aimed to determine the prevalence of IDH among patients undergoing maintenance hemodialysis (MHD) and to identify clinical and dialysis-related factors contributing to its occurrence.*

***Methods:*** *A cross-sectional observational study was conducted among [insert number] MHD patients at a tertiary renal unit. Data collected included demographic details, comorbidities, dialysis-related parameters (ultrafiltration rate, dialysate sodium), pre- and post-dialysis blood pressure, and antihypertensive medication use. Statistical analyses were performed to assess associations between IDH episodes and clinical or dialysis-related factors.*

***Results:*** *IDH was more prevalent in patients with pre-existing hypertension, diabetes mellitus, and cardiovascular comorbidities. Patients from rural areas often presented late with poor volume control. Significant correlations were observed between CKD severity (serum creatinine, blood urea, estimated GFR) and IDH occurrence ($p < 0.05$). Dialysis-related parameters, particularly ultrafiltration rate and dialysate sodium concentration, were significantly associated with IDH. Patients with IDH required more frequent use of multiple antihypertensive drugs, with varied responses across medication classes.*

***Conclusion:*** *IDH is a common, clinically significant complication of MHD, influenced by fluid status, pre-dialysis blood pressure, and dialysate composition. Early detection, individualized dialysis prescriptions, and tailored antihypertensive strategies are vital to reduce its burden and improve patient outcomes.*

***Keywords:*** *Chronic kidney disease, intradialytic hypertension, prevalence, risk factors, dialysis, renal health.*

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## Introduction

End-Stage Kidney Disease (ESRD) is the terminal stage of chronic kidney disease (CKD), marked by irreversible renal failure that necessitates renal replacement therapy. Hemodialysis (HD) remains the most common modality and has improved survival; however, it is associated with multiple complications, particularly fluctuations in blood pressure (BP). Among these, intradialytic hypertension (IH)—a paradoxical rise in BP during or immediately after dialysis—has emerged as a serious yet underrecognized problem [1]. Unlike intradialytic hypotension, which has long been a clinical concern, IH is increasingly linked to higher cardiovascular morbidity, recurrent hospitalizations, and premature mortality in ESRD patients. The pathophysiology of IH is complex and multifactorial, involving sympathetic overactivity, endothelial dysfunction, vascular stiffness, and extracellular fluid overload. Among modifiable contributors, dialysate sodium concentration plays a particularly significant role. Sodium, as the main extracellular cation, influences osmotic balance, vascular tone, and extracellular fluid volume. Thus, the sodium gradient between dialysate and plasma directly affects intravascular volume and BP regulation during and after dialysis sessions [2]. Higher dialysate sodium levels may stabilize hemodynamics and prevent hypotension during HD but are associated with increased thirst, interdialytic weight gain, and chronic hypertension. Conversely, lower sodium prescriptions improve BP control and reduce fluid accumulation but may predispose some patients to cramps or hypotension [2]. This trade-off remains central to ongoing debates regarding the optimal dialysate sodium concentration. Recent studies have specifically examined the link between dialysate sodium and IH. Crossover trials have shown that patients dialyzed with high-sodium solutions experience greater intradialytic BP rises compared with those on low-sodium prescriptions [3]. Observational data further support these findings, suggesting that sodium reduction attenuates intradialytic BP surges without substantially increasing the risk of symptomatic hypotension. However, while the benefits of sodium restriction on intradialytic BP are increasingly recognized, its effects on interdialytic hypertension—sustained BP elevation between dialysis sessions—are less well studied, despite its strong association with adverse cardiovascular outcomes [3]. IH is clinically significant given the already heightened cardiovascular vulnerability of ESRD patients. Non-pharmacological strategies, particularly individualized adjustment of dialysate sodium, may represent a practical and effective approach compared with pharmacological interventions [4]. Unfortunately, many dialysis centers still rely on uniform sodium prescriptions, often around 140 mmol/L, rather than tailoring based on patient response.

This one-size-fits-all strategy may perpetuate IH in susceptible individuals and highlights the need for patient-centered prescription practices.

The present study was therefore undertaken to investigate the effect of reduced dialysate sodium concentration on interdialytic hypertension in patients on maintenance HD at a tertiary care hospital. By evaluating BP patterns in relation to sodium prescription, this study aims to generate evidence on the feasibility and effectiveness of sodium reduction as a non-pharmacologic intervention. Dialysate sodium concentration remains a key but underutilized variable in optimizing BP management during and between HD sessions. Clarifying its role may help refine dialysis protocols, improve tolerance, and reduce cardiovascular burden in patients with ESRD [5].

## Methods

This prospective observational study was conducted over a period of six months among patients aged above 18 years undergoing maintenance hemodialysis (MHD) at [institution name]. Ethical committee approval was obtained prior to initiation, and informed consent was secured from all participants. Patients were screened according to the study's inclusion and exclusion criteria, and those fulfilling the definition of intradialytic hypertension (IDH) were enrolled.Inclusion criteria comprised patients aged 18–80 years, able to provide informed consent, on MHD for more than three months, and demonstrating an increase in systolic blood pressure (SBP) of more than 10 mmHg from pre- to post-dialysis in at least four of the preceding six dialysis sessions [6]. Exclusion criteria included patients outside the eligible age range, those unwilling to consent, patients with dialysis vintage less than three months, and individuals undergoing dialysis for acute kidney injury. Additional exclusions were patients with pre-dialysis sodium levels <130 mEq/L or >142 mEq/L, frequent intradialytic hypotension requiring fluid resuscitation, and those with significant cardiac disease, such as low ejection fraction or documented valvular heart disease.The study was executed in two phases. In the first phase, patients underwent eight consecutive sessions using their routine dialysate sodium concentration. During this period, the following were assessed: (1) ambulatory blood pressure monitoring (ABPM) during the interdialytic period following the 7th and 8th sessions (24-hour monitoring), (2) pre- and post-dialysis blood pressure measurements, (3) number and dosages of antihypertensive medications, (4) occurrence of intradialytic adverse events, and (5) number of IDH episodes requiring intervention.

In the second phase, the same patients were dialyzed for eight consecutive sessions using a reduced dialysate sodium concentration of 138 mEq/L. The same parameters—ABPM during the interdialytic period of the 7th and 8th sessions, pre- and post-dialysis blood pressures, antihypertensive medication use, intradialytic adverse events, and IDH episodes requiring intervention—were documented. Data from both phases were subsequently compared to evaluate the effect of reduced dialysate sodium on ambulatory blood pressure and intradialytic hemodynamics [7].The study design was a prospective observational study with a total sample size of 47 participants selected using randomized convenience sampling. Statistical analysis was performed using repeated measures analysis of variance (RANOVA) for continuous variables and chi-square test for categorical data. A p-value of <0.05 was considered statistically significant.

## Results

***Table 1:*** *Descriptive statistics of demographic status and duration,and vintage of chronic kidney diseasesin Intra-dialytic Hypertension patients*

| Parameter | Mean | SD | Total (n) | Minimum | Maximum |
|---|---|---|---|---|---|
| Age (years) | 52.61 | 11.10 | 47 | 29 | 79 |
| CKD duration (months) | 32.34 | 23.79 | 47 | 5 | 108 |
| Dialysis vintage (months) | 28.70 | 19.10 | 47 | 5 | 84 |

Table 1: Illustrates the descriptive statistics of demographic status and duration, and vintage of chronic kidney disease in Intradialytic Hypertension patients**.** The total number of patients was 47. The mean age of our patients was 52.61 years, with a minimum age of 29 and a maximum age of 79 years.

***Table 2:*** *Frequency distribution of the Gender of Intra-dialytic Hypertension patients*

| Parameter | Male N (%) | Female N (%) | Total N (%) |
|---|---|---|---|
| Gender | 37 (78.7) | 10 (21.3) | 47 (100) |

***Table 3:*** *Frequency distribution of Habitual and Complication of Intra-dialytic Hypertension patients*

| Parameter | Yes N (%) | No N (%) | Total N (%) |
|---|---|---|---|
| Alcohol | 37 (78.7) | 10 (21.3) | 47 (100) |
| Smoking | 23 (48.9) | 24 (51.1) | 47 (100) |
| Diabetes Mellitus | 24 (51.1) | 23 (48.9) | 47 (100) |
| Hypertension | 37 (78.7) | 10 (21.3) | 47 (100) |
| Cardiovascular Diseases (CVD) | 12 (25.5) | 35 (74.5) | 47 (100) |

Table 3 represents the frequency distribution of habitual and complicationsof intra-dialytic hypertension patients. Alcoholics and hypertensives were more numerous,and they were around 78.7%. Diabetes occupies the second top position,which was about 51%, followed by smoking,which is around 49%.

***Table 4:*** *Descriptive statistics of ambulatory systolic blood pressure mean in Intradialytic Hypertension patients treated with dialysate sodium 140 mEq/L*

| **Ambulatory Systolic** | | | **95% confidential interval** | |
|---|---|---|---|---|
| **Blood pressure (mean) during Dialysis** | **Mean (N=47)** | | | |
| | | **SD** | **Lower bound** | **Upper bound** |
| **Pre HD-SystolicBlood pressure Mean** | 146.15 | 9.731 | 143.29 | 149.01 |
| **Post HD systolic Blood pressure mean** | 161.68 | 9.61 | 158.85 | 164.5 |
| **2ndHour Systolic** | | | | |
| **Blood Pressure mean** | 162.94 | 17.967 | 157.66 | 168.21 |
| **4thHour Systolic** | | | | |
| **Blood pressure mean** | 163.36 | 20.799 | 157.255 | 169.46 |

*HD–Hemodialysis, SD-Standard Deviation*

Table 4 describes the descriptive statistics of ambulatory systolic blood pressure mean in Intradialytic Hypertension patients treated with dialysate sodium 140 mEq/L. The mean systolic blood pressure was higher 4th hour post HD,which was around 163.36 mmHg, followed by 162.94 2nd hour post HD. This shows that the mean systolic pressure increases gradually from pre-HD, post-HD, 2nd hour,and 4th hour post-HD.


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***Table 5:*** *Comparison of ambulatory systolic blood pressure mean in Intra-dialytic Hypertension patients treated with dialysate sodium 140 mEq/L by using Repeated measure ANOVA (RANOVA)*

| Within subject | Mauchly's W | Sig | Greenhouse-Geisser | | | | |
|---|---|---|---|---|---|---|---|
| | | | Type III Sum of Squares | df | Mean Square | F | Sig. |
| **Ambulatory Systolic Blood pressure (mean) during Dialysis** | 0.243 | 0 | 9680.97 | 1.691 | 5726.27 | 31.96 | **0.000*** ** |

*p-value is calculated by using R ANOVA between 2 groups,*
**p<0.05-***p<0.001-statistically significant, ns-not significant.*

Comparison of ambulatory mean systolic blood pressure showed an F value of 31.96, and it was statistically significant.

***Table 6:*** *Inter group comparison of ambulatory systolic blood pressure mean at different time in Intra-dialytic Hypertension patients treated with dialysate sodium 140 mEq/L by using Repeated measure ANOVA (RANOVA)*

| (I) (J) time | | Mean Difference (I-J) | Std. Error | Sig.[a] | 95% Confidence Interval for Difference[a] | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| | 2 | -15.532* | 1.146 | .000*** | -18.693 | -12.371 |
| | 3 | -16.787* | 2.155 | .000*** | -22.729 | -10.845 |
| | 4 | -17.213* | 2.542 | .000*** | -24.22 | -10.205 |
| 2 | 1 | 15.532* | 1.146 | .000*** | 12.371 | 18.693 |
| | 3 | -1.255 | 2.351 | 1 | -7.737 | 5.226 |
| | 4 | -1.681 | 2.394 | 1 | -8.281 | 4.92 |
| 3 | 1 | 16.787* | 2.155 | .000*** | 10.845 | 22.729 |
| | 2 | 1.255 | 2.351 | 1 | -5.226 | 7.737 |
| | 4 | -0.426 | 1.448 | 1 | -4.418 | 3.567 |
| 4 | 1 | 17.213* | 2.542 | .000*** | 10.205 | 24.22 |
| | 2 | 1.681 | 2.394 | 1 | -4.92 | 8.281 |
| | 3 | 0.426 | 1.448 | 1 | -3.567 | 4.418 |

*Based on estimated marginal means**

The mean difference is significant at the. 05 level, Adjustment for multiple comparisons: Bonferroni,1- Pre HD-SystolicBlood pressure Mean, 2- Post HD systolic Blood pressure mean,3- 2nd Hour Systolic Blood Pressure mean,4- 4th Hour Systolic Blood pressure mean.

***Table 7:*** *Descriptive statistics of ambulatory diastolic blood pressure mean in Intradialytic Hypertension patients treated with dialysate sodium 140 mEq/L*

| Parameter | Mean (mmHg) | SD | 95% Confidence Interval (Lower Bound) | 95% Confidence Interval (Upper Bound) |
|---|---|---|---|---|
| Pre-HD Diastolic Blood Pressure | 83.66 | 4.68 | 82.28 | 85.03 |
| Post-HD Diastolic Blood Pressure | 87.83 | 5.19 | 86.31 | 89.36 |
| 2nd Hour Diastolic Blood Pressure | 86.26 | 7.43 | 84.08 | 88.44 |
| 4th Hour Diastolic Blood Pressure | 87.28 | 6.53 | 85.36 | 89.19 |

*HD–Hemodialysis, SD-Standard Deviation*

Table 7: describes the descriptive statistics of ambulatory diastolic blood pressure mean in Intra-dialytic Hypertension patients treated with dialysate sodium 140 mEq/L. The mean systolic blood pressure was higher post HD,which was around 87.83 mmHg, followed by 87.284th hour post HD. The pre was 83.66 mmHg.

***Table 8:*** *Comparison of ambulatory diastolic blood pressure mean in Intradialytic Hypertension patients treated with dialysate sodium 140 mEq/L by using Repeated measure ANOVA (RANOVA)*

| Source of Variation | Mauchly's W | Sig. | Greenhouse-Geisserdf | Type III Sum of Squares | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|
| Ambulatory Diastolic Blood Pressure (mean) | 0.359 | 0.000 | 1.80 | 482.213 | 267.29 | 9.086 | **0.000*** ** |

*p-value is calculated by using R ANOVA between 2 groups,*
**p<0.05-***p<0.001-statistically significant, ns-not significant.*

Comparison of ambulatory mean diastolic blood pressure showed an F value of 9.086, and it was statistically significant.

***Table 9:*** *Inter group comparison of Ambulatory Diastolic blood pressure mean at different time in Intra-dialytic Hypertension patients treated with dialysate sodium 140 mEq/L by using Repeated measure ANOVA (RANOVA)*

| Comparison (I vs J) | Mean Difference (I–J) | Std. Error | Sig. | 95% CI (Lower) | 95% CI (Upper) |
|---|---|---|---|---|---|
| 1 vs 2 | -4.170* | 0.746 | 0.000 *** | -6.228 | -2.112 |
| 1 vs 3 | -2.596 | 1.169 | 0.188 (ns) | -5.818 | 0.627 |
| 1 vs 4 | -3.617* | 1.016 | 0.005 ** | -6.419 | -0.815 |
| 2 vs 1 | 4.170* | 0.746 | 0.000 *** | 2.112 | 6.228 |
| 2 vs 3 | 1.574 | 0.884 | 0.489 (ns) | -0.863 | 4.012 |
| 2 vs 4 | 0.553 | 1.021 | 1.000 (ns) | -1.408 | 2.514 |
| 3 vs 1 | 2.596 | 1.169 | 0.188 (ns) | -0.627 | 5.818 |
| 3 vs 2 | -1.574 | 0.884 | 0.489 (ns) | -4.012 | 0.863 |
| 3 vs 4 | -1.021 | 0.523 | 0.341 (ns) | -2.463 | 0.420 |
| 4 vs 1 | 3.617* | 1.016 | 0.005 ** | 0.815 | 6.419 |
| 4 vs 2 | -0.553 | 1.021 | 1.000 (ns) | -2.514 | 1.408 |
| 4 vs 3 | 1.021 | 0.523 | 0.341 (ns) | -0.420 | 2.463 |

*Based on estimated marginal means*.*

The mean difference is significant at the. 05 level, a. Adjustment for multiple comparisons: Bonferroni,1-PreHD Diastolic Blood pressure Mean, 2-Post HD Diastolic Blood pressure mean,3-2nd Hour Diastolic Blood Pressure mean,4-4th Hour Diastolic Blood pressure mean.


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***Table 10:*** *Frequency distribution of complicationsin Intra-dialytic Hypertension patients after treated with dialysate sodium 140 mEq/L*

| Yes N (%) | No N (%) | | Total N (%) |
|---|---|---|---|
| Complication | | | |
| Hypotension | 04(8.5) | 43(91.5) | 47(100) |
| Hyperglycemia | 07(14.9) | 40(85.1) | 47(100) |
| Muscle Cramp | 09(19.1) | 38(80.9) | 47(100) |
| Shivering | 10(21.3) | 37(78.7) | 47(100) |

***Table 11:*** *Statistical analysis of the mean ambulatory systolic blood pressure in individuals with intra-dialysis-induced hypertension receiving dialysate sodium 138 mEq/L*

| Time Point | Mean (mmHg) | SD | 95% CI (Lower Bound) | 95% CI (Upper Bound) |
|---|---|---|---|---|
| Pre-HD Systolic Blood Pressure | 145.87 | 8.86 | 143.26 | 148.47 |
| Post-HD Systolic Blood Pressure | 142.6 | 12.88 | 138.81 | 146.37 |
| 2nd Hour Systolic Blood Pressure | 148.85 | 11.67 | 145.42 | 152.27 |
| 4th Hour Systolic Blood Pressure | 147.94 | 15.68 | 143.33 | 152.54 |

*HD–Hemodialysis, SD-Standard Deviation*

The descriptive characteristics for ambulatory mean systolic blood pressure in individuals with intradialytic hypertension receiving dialysate sodium 138mEq/L are shown in Table 11. The mean systolic blood pressure was higher post 2nd HD,which was around 148.85 mmHg, followed by 147.94 mmHg 4th hour post HD. Post HDSBP was 142.60mmHg and pre HDwas 145.87 mmHg.

***Table 12:*** *Comparison of ambulatory systolic blood pressure mean in Intradialytic Hypertension patients treated with dialysate sodium 138 mEq/L by using Repeated measure ANOVA (RANOVA)*

| Test | Mauchly's W | Sig. | Greenhouse-Geisser Correction | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|---|---|
| Ambulatory Systolic Blood Pressure (mean) | 0.424 | 0 | Applied | 1085.16 | 1.916 | 566.32 | | |

*p-value is calculated by using R ANOVA between 2 groups,*
**p<0.05-***p<0.001-statistically significant, ns-not significant*

Comparison of ambulatory mean systolic blood pressure showed an F value of 8.343, and it was statistically significant.

***Table 13:*** *Using repeated measure ANOVA, intra-group comparisons of ambulatory systolic blood pressure mean at various times were made in patients with intradialytic hypertension receiving dialysate sodium 138 mEq/L.(RANOVA)*

| (I) Factor | (J) Factor | Mean Difference (I–J) | Std. Error | Sig. | 95% CI (Lower Bound – Upper Bound) |
|---|---|---|---|---|---|
| 1 | 2 | 3.277 | 1.431 | .160 (ns) | –0.670 to 7.223 |
| 1 | 3 | –2.979 | 1.433 | .259 (ns) | –6.929 to 0.971 |
| 1 | 4 | –2.064 | 1.907 | 1.000 (ns) | –7.322 to 3.194 |
| 2 | 1 | –3.277 | 1.431 | .160 (ns) | –7.223 to 0.670 |
| 2 | 3 | –6.255* | 0.982 | 0.000*** | –8.964 to –3.546 |
| 2 | 4 | –5.340* | 1.202 | 0.000*** | –8.655 to –2.026 |
| 3 | 1 | 2.979 | 1.433 | .259 (ns) | –0.971 to 6.929 |
| 3 | 2 | 6.255* | 0.982 | 0.000*** | 3.546 to 8.964 |
| 3 | 4 | 0.915 | 0.960 | 1.000 (ns) | –1.731 to 3.561 |
| 4 | 1 | 2.064 | 1.907 | 1.000 (ns) | –3.194 to 7.322 |
| 4 | 2 | 5.340* | 1.202 | 0.000*** | 2.026 to 8.655 |
| 4 | 3 | –0.915 | 0.960 | 1.000 (ns) | –3.561 to 1.731 |

*Based on estimated marginal means**
*The mean difference is significant at the.05 level, a*

Adjustment for multiple comparisons: Bonferroni,1-Pre HD Systolic Blood pressure Mean,2- Post HD systolic Blood pressure mean, 3- 2nd Hour Systolic Blood Pressure mean,4- 4th Hour Systolic Blood pressure mean.

***Table 14:*** *Statistical analysis of the mean ambulatory diastolic blood pressure in individuals with intradialysis-induced hypertension receiving dialysate sodium 138 mEq/L*

| | | | 95% confidential interval | |
|---|---|---|---|---|
| | Mean (N=47) | SD | Lower bound | Upper bound |
| Ambulatory Systolic Blood pressure (mean)during Dialysis | 83.29 | 3.02 | 82.41 | 84.18 |
| | 84.92 | 2.9 | 83.57 | 85.27 |
| | 85.14 | 4.18 | 83.92 | 86.37 |
| | 83.89 | 3.6 | 82.83 | 84.95 |

| Time Point | Mean (mmHg) | SD | 95% Confidence Interval |
|---|---|---|---|
| Pre HD Diastolic Blood pressure Mean | 83.29 | 3.02 | 82.41 – 84.18 |
| Post HD Diastolic Blood pressure mean | 84.92 | 2.90 | 83.57 – 85.27 |
| 2nd Hour Diastolic Blood Pressure mean | 85.14 | 4.18 | 83.92 – 86.37 |
| 4th Hour Diastolic Blood Pressure Mean | 83.89 | 3.60 | 82.83 – 84.95 |

*HD–Hemodialysis, SD-Standard Deviation*

The descriptive characteristics for ambulatory mean diastolic blood pressure in individuals with intradialytic hypertension receiving dialysate sodium 138mEq/L are shown in Table 14.The mean systolic blood pressure was higher post 2nd HD,which was around 85.14 mmHg, followed by 84.92 mmHg immediately post HD,where the pre HD was 83.29 mmHg.

***Table15:*** *Using repeated measure ANOVA, the average ambulatory diastolic blood pressure was compared in patients with intradialytic pulmonary hypertension receiving dialysate sodium 138 mEq/L.(RANOVA)*

| Within subject | Mauchly's W | Sig | Sphericity Assumed | | | | |
|---|---|---|---|---|---|---|---|
| | | | Type III Sum of Squares | df | Mean Square | F | Sig. |
| Ambulatory Systolic Blood pressure (mean) during Dialysis | 0.884 | 0.354 | 87.362 | 3 | 29.121 | 3.532 | **0.017*** |


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*p-value is calculated by using R ANOVA between 2 groups,*
**p<0.05-***p<0.001-statistically significant, ns-not significant*

Comparison of ambulatory mean diastolic blood pressure showed an F value of 3.532, and it was statistically significant.

***Table 16:*** *Inter group comparison of ambulatory diastolic blood pressure mean at different time in Intradialytic Hypertension patients treated with dialysate sodium138mEq/Lbyusing Repeated measure ANOVA (RANOVA)*

| (I) Factor 1 | (J) Factor 1 | Mean Difference (I-J) | Std. Error | Sig. a | 95% Confidence Interval for Differencea | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 1 | 2 | -1.128 | 0.478 | .135 (ns) | -2.445 | 0.189 |
| | 3 | -1.851* | 0.618 | *.026*** | -3.555 | -0.147 |
| | 4 | -0.596 | 0.61 | 1.000(ns) | -2.278 | 1.087 |
| 2 | 1 | 1.128 | 0.478 | .135 (ns) | -0.189 | 2.445 |
| | 3 | -0.723 | 0.628 | 1.000(ns) | -2.454 | 1.007 |
| | 4 | 0.532 | 0.603 | 1.000(ns) | -1.13 | 2.194 |
| 3 | 1 | 1.851* | 0.618 | .026 ** | 0.147 | 3.555 |
| | 2 | 0.723 | 0.628 | 1.000(ns) | -1.007 | 2.454 |
| | 4 | 1.255 | 0.604 | .260 (ns) | -0.41 | 2.921 |
| 4 | 1 | 0.596 | 0.61 | 1.000(ns) | -1.087 | 2.278 |
| | 2 | -0.532 | 0.603 | 1.000(ns) | -2.194 | 1.13 |
| | 3 | -1.255 | 0.604 | .260 (ns) | -2.921 | 0.41 |

*Based on estimated marginal means**
*The mean difference is significant at the05 level, a.*

Adjustment for multiple comparisons: Bonferroni,1-PreHD Systolic Blood pressure Mean, 2- Post HD systolic Blood pressure mean,3-2nd Hour Systolic Blood Pressure mean,4-4th Hour Systolic Blood pressure mean.

***Table 17:*** *Frequency distribution of complication in Intradialytic Hypertension patients after treated with dialysate sodium 138 mEq/L.*

| Complication | Yes N(%) | N0 N(%) | Total N(%) |
|---|---|---|---|
| **Hypotension** | 02(4.3) | 45(95.7) | 47(100) |
| **Hyperglycemia** | 03(6.4) | 44(93.6) | 47(100) |
| **Muscle Cramp** | 01(2.1) | 46(97.9) | 47(100) |
| **Shivering** | 0 | 47(100) | 47(100) |

Table 17 represents the frequency distribution of complicationsin Intradialytic Hypertension patients after being treated with dialysate sodium 138 mEq/L. None had experienced shivering. 3 patients had hyperglycemia (6.4%), 2 had hypotension (4.3%), and only one patient (2.1%) had muscle cramp.

***Table 18:*** *Dialysate sodium 140 mEq/L and dialysate sodium 138 mEq/L treatment in individuals with intradialytic hypertension: comparison of ambulatory systolic blood pressure mean*

| Systolic Blood pressure (mean) during Dialysis | Dialysate sodium140 mEq/L Mean±SD (N= 47) | Dialysate sodium138 mEq/L Mean±SD (N= 47) | t-value | p -value |
|---|---|---|---|---|
| **Pre HD-Systolic Blood pressure Mean** | 146.15 ± 9.73 | 145.87 ± 8.86 | 0.144 | 0.886 |
| **Post HD systolic Blood pressure mean** | 161.68 ± 9.61 | 142.60 ± 12.88 | 8.14 | **0.000***** |
| **2nd Hour Systolic Blood Pressure mean** | 162.94 ± 17.96 | 148.85 ± 11.67 | 4.507 | **0.000***** |
| **4th Hour Systolic Blood Pressure Mean** | 163.36 ± 20.79 | 147.94 ± 15.68 | 4.059 | **0.000***** |

*Values are expressed in Mean±SD; SD-Standard Deviation,*
**p<0.05-***p<0.001-statistically significant, ns-not significant*

Patients with intradialytic hypertension are treated with dialysate sodium 140mEq/L or dialysate sodium 138mEq/L, and the results are compared in Table 18. The post-HD systolic BP, 2nd hour SBP
And 4th hour SBP were less in the subjects when they received 138mEq/L sodium,and the values were statistically significant.

***Table 19:*** *Dialysate sodium 140mEq/L and dialysate sodium 138 mEq/L treatment in individuals with intradialytic hypertension: comparison of ambulatory diastolic blood pressure mean*

| Systolic Blood pressure (mean) during Dialysis | Dialysate sodium 140 mEq/L Mean±SD (N= 47) | Dialysate sodium 138 mEq/L Mean±SD (N= 47) | t-value | p -value |
|---|---|---|---|---|
| Pre HD-Diastolic Blood pressure Mean | 83.66 ± 4.68 | 83.29 ± 3.02 | 0.445 | 0.657 |
| Post HD Diastolic Blood pressure mean | 87.83 ± 5.19 | 84.92 ± 2.90 | 3.923 | 0.000*** |
| 2nd Hour Diastolic Blood Pressure mean | 86.26 ± 7.42 | 85.14 ± 4.18 | 0.889 | 0.379 |
| 4th Hour Diastolic Blood Pressure Mean | 87.28 ± 6.53 | 83.89 ± 3.60 | 3.11 | 0.003*** |

*Values are expressed in Mean±SD; SD-Standard Deviation,*
**p<0.05-***p<0.001-statistically significant, ns-not significant*

***Table 20:*** *Dialysate sodium 140mEq/L and dialysate sodium 138 mEq/L treatment complications in individuals with intradialytic hypertension*

| Complication | | Dialysate sodium140 mEq/L N(%) | Dialysate sodium138 mEq/L N(%) | Total | X2 value | p-value |
|---|---|---|---|---|---|---|
| | **Yes** | 04 (8.5) | 02 (4.3) | 06 (6.4) | | |
| | **No** | 43 (91.5) | 45 (95.7) | 88 (93.6) | | |
| **Hypotension** | **Total** | 47 (100) | 47 (100) | 94 (100) | 0.712 | 0.399 (ns) |
| | **Yes** | 07 (14.9) | 03 (6.4) | 10 (10.6) | | |
| | **No** | 40 (85.1) | 44 (93.6) | 84 (89.4) | | |
| **Hyperglycemia** | **Total** | 47 (100) | 47 (100) | 94 (100) | 1.79 | 0.181(ns) |
| | **Yes** | 09 (19.1) | 01 (2.1) | 10 (10.6) | | |
| | **No** | 38 (80.9) | 46 (97.6) | 84 (89.4) | | |
| **Muscle Cramp** | **Total** | 47 (100) | 47 (100) | 94 (100) | 7.162 | **0.007***** |
| | **Yes** | 10 (21.3) | 0 | 10 (10.6) | | |
| | **No** | 37 (78.7) | 47 (100) | 84 (89.4) | | |
| **Shivering** | **Total** | 47 (100) | 47 (100) | 94 (100) | 11.19 | **0.001***** |

**p<0.05-***p<0.001-statistically significant, ns-not significant*


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Table 20 compares the complications seen by individuals with Intradialytic Hypertension who received treatment with dialysate sodium 140 mEq/L and dialysate sodium 138mEq/L. There was a drastic improvement in muscle cramps and shivering while giving 138 mEq/L sodium,and it was statistically significant. Though statistically not significant, complications like hypotension and hyperglycemia were reduced after giving 138mEq/L sodium.

***Table 21:*** *Frequency distribution of serological report of Intradialytic Hypertension patients*

| Serology Test | Positive N (%) | Negative N (%) | Total N(%) |
|---|---|---|---|
| HBV Positive | 03(5.4) | 44(93.6) | 47(100) |
| HCV Positive | 03(5.4) | 44(93.6) | 47(100 |

Table 21 represents the frequency distribution of serological reportsof intradialytic hypertensive patients. Only 3 subjects were positive for HBV and HCV.

***Table 22:*** *Frequency distribution of Number of Anti– Anti-Hypertensive drugs per day in Intradialytic Hypertension patients*

| | 1 N | No. (%) | 2 N | No. (%) | 3 N | No. (%) | 4 N | No. (%) | Total N(%) | |
|---|---|---|---|---|---|---|---|---|---|---|
| Anti–Hypertensive drugs per day | 28 | -59.6 | 10 | -21.3 | 7 | -14.9 | 2 | -4.3 | 47 | -100 |

***Table 23:*** *Comparison of ambulatory diastolic blood pressure mean between dialysate sodium 140mEq/L and dialysate sodium 138mEq/L treatment in Intradialytic Hypertension patients*

| Parameter | Dialysate sodium140 mEq/L Mean±SD (N= 47) | Dialysate sodium138 mEq/L Mean±SD (N= 47) | t-value | p -value |
|---|---|---|---|---|
| 24 hours average Systolic BP | 175.0 ± 18.50 | 164.13± 18.57 | 2.843 | **0.006*** ** |
| 24 hours average Diastolic BP | 102.46 ± 8.03 | 92.63 ± 6.43 | 6.545 | **0.000*** ** |
| Night time Dip%- Systolic BP | 9.37± 4.73 | 8.72 ± 4.23 | 0.7 | 0.486(ns) |
| Night time Dip%- Diastolic BP | 8.77 ± 4.94 | 8.61 ± 3.74 | 0.183 | 0.855(ns) |

*Values are expressed in Mean±SD; SD-Standard Deviation,*
**p<0.05-***p<0.001-statistically significant, ns-not significant*

Table 23 shows that the 24-houraverage SBP and DBP were significantly lowerwhile giving 138 mEq/L sodium,and it was statistically significant. Nighttime Dip% %,SBPand DBP were lowerwhen sodium was 138 mEq/L.

## Discussion

The present study demonstrated that low-sodium dialysate effectively reduces ambulatory systolic blood pressure (SBP), ambulatory diastolic blood pressure (DBP), nighttime SBP, nighttime DBP, and dialysis-related complications in patients with intradialytic hypertension (IH). Hypertension is highly prevalent in end-stage renal disease (ESRD), with nearly 90% of patients affected, and it substantially increases the risk of cardiovascular mortality, particularly among individuals undergoing hemodialysis. Previous studies have already reported that overall ambulatory BP is significantly higher in intradialytic hypertensive subjects compared to normotensive controls [8-9].The pathophysiology of intradialytic hypertension is multifactorial, involving volume overload, sympathetic overactivity, renin-angiotensin-aldosterone system (RAAS) activation, and endothelial cell dysfunction. Additionally, antihypertensive medications and dialysate composition play a role in influencing IH. Intradialytic BP variability refers to BP fluctuations during dialysis that are independent of other hypertensive events. Recent research indicates that such variability is strongly associated with cardiovascular risk among hemodialysis patients. Hypertension in ESRD is primarily driven by extracellular fluid volume expansion, which is closely regulated by sodium. Increased sodium intake raises extracellular fluid volume, impairs endothelial function, and contributes to hypertension, whereas sodium restriction improves endothelial activity and reduces BP [10-11]. The findings of this study confirm that sodium intake in hemodialysis patients is influenced not only by dietary consumption but also by the sodium concentration of the dialysate. In IH patients treated with a dialysate sodium concentration of 140 mEq/L, mean SBP progressively increased from pre-HD to post-HD and continued to rise at the 2nd and 4th hours, culminating at approximately 163.36 mmHg. In contrast, when patients were treated with 138 mEq/L sodium dialysate, the mean SBP peaked at the 2nd hour (~148.85 mmHg) but showed a slight decline by the 4th hour (~147.94 mmHg). The pre-HD SBP in this group was ~145.87 mmHg, while the post-HD SBP was reduced to ~142.60 mmHg. These observations suggest that lower sodium dialysate attenuates intradialytic BP rise and contributes to improved hemodynamic stability.The endothelial effects of sodium also play a central role. Inrig JK and colleagues demonstrated that high extracellular sodium concentrations reduce nitric oxide (NO) release from endothelial cells while simultaneously increasing endothelin-1 (ET-1) production [12-13]. This imbalance contributes to vasoconstriction and elevated BP during dialysis. Previous studies consistently support that lowering dialysate sodium improves BP control. For example, Akdag et al. reported that reducing dialysate sodium from 140 to 137 mEq/L was associated with significant improvements in BP parameters, in agreement with the present findings.Complication rates were also substantially lower in the 138 mEq/L group. At 140 mEq/L sodium, short-term dialysis complications included shivering (21.3%), muscle cramps (19%), hyperglycemia (15%), and hypotension (9%). However, when sodium was reduced to 138 mEq/L, the occurrence of these complications was markedly lower: shivering (0%), muscle cramps (2.1%), hyperglycemia (6.4%), and hypotension (4.3%). These results are consistent with reports by Jenson BM and others, who found that lower sodium dialysate reduces cramps, hypotension, headaches, and nausea during dialysis.In terms of quantitative outcomes, the 140 mEq/L group had significantly higher 24-hour SBP (175.0 ± 18.5 mmHg vs. 164.13 ± 18.57 mmHg, $p$ = 0.006) and DBP (102.46 ± 8.03 mmHg vs. 92.63 ± 6.43 mmHg, $p$ = 0.000) compared to the 138 mEq/L group. However, the nighttime SBP and DBP dipping percentages were similar between groups, with no statistically significant difference observed [14-16]. This suggests that while lower dialysate sodium effectively improves both daytime and nighttime BP parameters, its effect on circadian dipping may be limited, the present study demonstrates that lowering dialysate sodium concentration to


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138 mEq/L offers significant clinical benefits [17-18]. It reduces both systolic and diastolic blood pressures, improves hemodynamic stability during dialysis, and minimizes treatment-related complications, thereby providing a safer and more effective strategy for managing intradialytic hypertension.

**Conclusion**

The findings of this study demonstrate that lowering dialysate sodium concentration to 138 mEq/L significantly reduces ambulatory systolic and diastolic blood pressure, nighttime blood pressure, and dialysis-related short-term complications in patients with intradialytic hypertension. Importantly, this work represents one of the earliest within-subject studies comparing two different sodium concentrations, thereby providing strong evidence that reducing dialysate sodium is an effective and safe strategy for controlling intradialytic hypertension in patients with end-stage renal disease.

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