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Original article

An observational study to assess the efficacy of ambulatory blood pressure monitoring in hypertension management among chronic kidney disease patients

Rishabh Gupta[1], Varadharajan Jayaprakash[1], Arunkumar Asokan[1], and Gerry George Mathew[1]

[1]Nephrology Department, SRM Medical College Hospital and Research Centre, Kattankulathur, Tamil Nadu, India

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Abstract

Introduction: Chronic kidney disease (CKD) poses a significant global health challenge and is often associated with hypertension (HTN) and cardiovascular diseases (CVD). Ambulatory blood pressure monitoring (ABPM) is a promising approach for precise blood pressure assessment, particularly in patients with chronic kidney disease. This study aimed to evaluate the efficacy of ABPM in managing blood pressure (BP) in patients with end-stage renal disease (ESRD) undergoing haemodialysis.

Objective: This study aimed to compare the effectiveness of ambulatory blood pressure monitoring as an adjunct to routine blood pressure management in achieving optimal blood pressure control among patients on haemodialysis. The secondary objectives included a study of the variation in systolic blood pressure (SBP), diastolic blood pressure (DBP) and mean arterial pressure

Keywords: Chronic kidney disease, Ambulatory blood pressure monitoring, Haemodialysis, Hypertension, Twice-weekly haemodialysis.

Correspondence: Gerry George Mathew, SRM Medical College Hospital and Research Centre, Chennai, Tamil Nadu, 603203, India. E-mail: mathewgg@srmist.edu.in

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(MAP) at baseline and at 3 months, along with variations of night-time and daytime blood pressure in haemodialysis patients.
Materials and methods: A comparative prospective study was conducted, enrolling 62 patients with chronic kidney disease undergoing haemodialysis twice weekly. ABPM was added to the routine blood pressure monitoring in the experimental group, whereas only routine blood pressure monitoring was conducted in the control group. Demographic data, pre- and post-haemodialysis blood pressure, ABPM recordings, and laboratory parameters were collected. Data analysis included descriptive statistics, t-tests, and chi-square tests.
Results: The mean ages of participants in the experimental and control groups were 52 ± 16.7 years and 47.9 ± 14.3 years, respectively. The study found that ABPM significantly improved blood pressure control compared with routine monitoring at the end of 3 months. Statistically significant differences were observed in mean systolic blood pressure (140 ± 12.7 vs. 151 ± 17.6, P=0.006), diastolic blood pressure (84 ± 6.2 vs. 89 ± 8.6, P=0.011) and mean arterial pressure (106 ± 7 vs. 110 ± 8.4, P=0.046) between the two groups.
Conclusion: Our study emphasizes ABPM's vital role in improving blood pressure management in CKD patients on haemodialysis and also in identifying the nuances of blood pressure variation in this vulnerable population.

Estudio observacional para evaluar la eficacia del monitoreo ambulatorio de la presión arterial en el manejo de la hipertensión en pacientes con enfermedad renal crónica

Resumen

Introducción: la enfermedad renal crónica (ERC) representa un importante desafío para la salud global, a menudo complicada por hipertensión (HTA) y enfermedad cardiovascular. El monitoreo ambulatorio de la presión arterial (MAPA) proporciona una evaluación precisa de la presión arterial (PA) en la enfermedad renal crónica, particularmente en pacientes con enfermedad renal terminal (ERT) en hemodiálisis.
Objetivo: comparar el monitoreo ambulatorio de la presión arterial como complemento al monitoreo rutinario para lograr un control óptimo de la presión arterial en pacientes en hemodiálisis. Los objetivos secundarios fueron evaluar los cambios desde el inicio hasta los 3 meses en presión arterial sistólica (PAS), diastólica (PAD), presión arterial media (PAM) y la presión arterial diurna y nocturna en pacientes con hemodiálisis.
Material y métodos: este estudio observacional comparativo y prospectivo incluyó a 62 pacientes con ERC (31 experimentales, 31 controles) en hemodiálisis dos veces por semana en un centro terciario. El grupo experimental recibió monitoreo ambulatorio de la presión arterial y monitoreo rutinario; en el grupo de control, solo se realizó monitoreo rutinario. Se recolectaron datos demográficos, presión arterial pre-/post-diálisis, perfiles de MAPA de 24 horas y parámetros de laboratorio. El análisis utilizó estadística descriptiva, pruebas t de Student independientes y prueba de chi-cuadrado (p <0,05).
Resultados: las edades medias fueron 52 ± 16,7 años (experimental) y 47,9 ± 14,3 años (control). A los 3 meses, el monitoreo ambulatorio de la presión arterial mostró un control superior de la PA: sistólica

media (140 ± 12,7 vs 151 ± 17,6 mmHg, p = 0,006), diastólica (84 ± 6,2 vs 89 ± 8,6 mmHg, p = 0,011), y media (106 ± 7 vs 110 ± 8,4 mmHg, p = 0,046).
Conclusión: el monitoreo ambulatorio de la presión arterial mejora significativamente el manejo de la presión arterial y revela patrones de variabilidad en pacientes con enfermedad renal crónica en hemodiálisis dos veces por semana, justificando su adopción en atención terciaria.

Palabras clave: enfermedad renal crónica, monitoreo ambulatorio de la presión arterial, hemodiálisis, hipertensión, diálisis dos veces por semana.

Introduction

Chronic kidney disease (CKD) presents a significant health challenge, affecting approximately 11 to 13 % of the global population, and is steadily increasing in prevalence [1, 2]. Among CKD patients, hypertension (HTN) is highly prevalent, with rates ranging from 80 to 85 %, significantly surpassing those of the general population [3, 4]. This heightened prevalence is not merely coincidental but intricately linked to the progression of kidney dysfunction and the concomitant development of cardiovascular disease (CVD), which contributes substantially to mortality rates [5, 6].

Conventional methods of blood pressure (BP) monitoring, primarily office-based measurements, face notable limitations in accurately capturing the dynamic fluctuations of BP over a 24-hour period. These methods provide only a snapshot evaluation, potentially overlooking crucial diurnal and nocturnal variations in BP [7]. Such limitations hinder precise BP control, especially in populations with heightened susceptibility to BP variability, such as CKD patients undergoing dialysis.

Ambulatory blood pressure monitoring (ABPM), a pivotal advancement over conventional monitoring techniques, offers a holistic assessment of BP patterns, including nocturnal hypertension and masked hypertension, which are particularly pertinent in the CKD population on dialysis. By providing continuous monitoring over a 24-hour period, ABPM captures the intricacies of BP dynamics that may elude sporadic office-based measurements [8, 9]. Evidence suggests that ABPM-guided therapy enhances BP control, mitigates cardiovascular risk, and improves overall patient outcomes compared to traditional monitoring methods [10–12]. By offering a more comprehensive understanding of BP fluctuations, ABPM empowers healthcare providers to tailor treatment strategies more effectively.

Despite the evident advantages of ABPM, there is a notable research gap concerning its utility in the specific context of CKD patients undergoing twice-weekly dialysis, which is a prevalent practice pattern in resource-strained countries. Addressing this gap, our study aims

to evaluate the optimal control of BP management outcomes with and without ABPM in end-stage renal disease (ESRD) patients undergoing haemodialysis twice weekly.

Methodology

This comparative prospective study was conducted in the Nephrology Department at SRM Medical College Hospital and Research Centre from November 2023 to April 2024. The study population included all eligible CKD patients on maintenance haemodialysis for more than 3 months with urea reduction ratio (URR) exceeding 65 %. Inclusion criteria consisted of CKD patients on regular haemodialysis twice weekly, aged between 18 and 60 years, with a minimum of 3 months of dialysis vintage, and those receiving haemodialysis via arteriovenous fistula. Exclusion criteria included CKD patients on haemodialysis thrice weekly, individuals with gross heart failure (ejection fraction <30 %), patients with recent coronary artery disease within 1 month, those with dialysis vintage less than 3 months, patients under 18 years old, and pregnant patients.

The primary objective of the study was to examine the effectiveness of the addition of ABPM to routine blood pressure measurement in the optimal control of blood pressure at the end of 3 months. The secondary objectives included identification of variation in daytime and night-time ambulatory blood pressure in haemodialysis patients and identification of the changes in systolic blood pressure (SBP), diastolic blood pressure (DBP), pulse pressure (PP), heart rate (HR), and mean arterial pressure (MAP) at baseline and at 3 months.

The sample size was calculated based on a study by Indhumathi *et al.* [13], enrolling 62 CKD patients. Participants were allocated to Group A (ABPM with routine BP monitoring group) and Group B (routine BP monitoring alone group), with 31 patients in each group. The sampling technique employed was consecutive sampling, where all eligible patients were included in the study until the desired sample size of 62 patients was achieved. Informed written consent was obtained from all participants before inclusion in the study. Routine laboratory investigations were performed before dialysis within 4 weeks of ABPM measurements. This study was approved by the institutional ethics committee (SRMIEC-ST0723-1229).

Routine BP measurements

Pre-dialysis BP was routinely measured manually using a standardized aneroid sphygmomanometer just before the dialysis unit's initiation by dialysis staff members, every 30 minutes during, and at the end of dialysis. As per the National Kidney Foundation's Kidney Disease

Outcomes Quality Initiative (KDOQI) guidelines, a pre-dialysis BP of >140/90 mmHg and a post-dialysis BP of >130/80 mmHg were considered uncontrolled BP [12].

ABPM procedure

Patients underwent ambulatory blood pressure monitoring (ABPM) after a mid-week hemodialysis session. The device used in the study was the PM50 model manufactured by Contec Medical Systems Co. Ltd. Patients wore the ABPM device on their non-access arm after the dialysis session, activating it for 24 hours during the non-dialysis period. Although ABPM recording during the interdialytic period of 44 hours would be better, 24-hour monitoring was chosen for patient convenience and better compliance.

Blood pressure was recorded every 30 minutes from 10 a.m. to 10 p.m. and hourly from 10 p.m. to 10 a.m. Patients were advised to continue their routine activities and antihypertensive medications as instructed by the clinician. Recorded values were collected during their subsequent dialysis visit. The recordings were downloaded using the manufacturer's software, and if the monitor malfunctioned, repeat monitoring was performed to ensure at least 70 % of BP values were valid.

Daytime or active-period SBP $\geq$135 mmHg was considered uncontrolled BP, and nighttime or passive-period BP $\geq$120 mmHg was also considered uncontrolled BP [13]. Nocturnal dipping status of BP was defined as a fall in average nighttime SBP exceeding 10 % of average daytime SBP. Antihypertensives were titrated to target optimal blood pressure as per ABPM readings in the experimental group and routine BP measurements in the control group. ABPM was used only once at baseline in the intervention group for treatment adjustment. The patients' blood pressures in both arms were reassessed at 3 months post-intervention and titration of antihypertensives; this phase is termed the post-assessment phase as per the study protocol.

Data collection involved documenting demographic data and anthropometric data, laboratory parameters, pre- and post-haemodialysis blood pressure, ABPM recordings, and other relevant variables in a case record form.

Statistical analysis

The data collected was entered into Microsoft Excel, and a master chart was created. The data from the master chart was exported to the Statistical Package for Software Solutions (SPSS) version 21 for analysis. The analysis comprised various statistical techniques, including

descriptive statistics, t-tests, and chi-square tests. A significance level of P<0.05 was applied throughout the analysis, with results meeting this criterion considered statistically significant.

Results

In this study, 62 patients with chronic kidney disease (CKD) were enrolled and allocated equally into two groups of 31 patients each. In Group A, ambulatory blood pressure monitoring (ABPM) was added to routine blood pressure (BP) monitoring, while only routine BP monitoring was conducted in Group B. The mean ages of participants in the experimental and control groups were 52±16.7 years and 47.9±14.3 years, respectively. Demographic characteristics, as shown in table 1, were similar between the groups.

Table 1. Distribution of demographic characteristics of the participants

Demographic variables		Group				Total		Chi-square value	P value
		Group A		Group B					
Age (years)	<20	2	6.5 %	1	3.2 %	3	4.8 %	3.7	0.296
	20-40	7	22.6 %	8	25.8 %	15	24.2 %		
	40-60	9	29.0 %	15	48.4 %	24	38.7 %		
	>60	13	41.9 %	7	22.6 %	20	32.3 %		
	Mean ± SD	52±16.7		47.9±14.3					
Gender	Female	10	32.3 %	5	16.1 %	15	24.2 %	2.199	0.138
	Male	21	67.7 %	26	83.9 %	47	75.8 %		
Diabetes *mellitus*	No	20	64.5 %	22	71.0 %	42	67.7 %	0.295	0.587
	Yes	11	35.5 %	9	29.0 %	20	32.3 %		

Source: Authors.

All variables except potassium followed a normal distribution. There was no statistically significant difference found between the groups (P=0.180). However, in the comparison of clinical parameters, bicarbonate and phosphorus levels were significantly higher in the group receiving ABPM (P=0.016 and P=0.001, respectively). Conversely, other clinical parameters such as haemoglobin (Hb), albumin, sodium, potassium, and calcium were similar across both groups (table 2).

Table 2. Comparison of anthropometric and clinical data of patients between groups

Variables	Group A	Group B	t value (or) Mann Whitney U value	P value
BMI[a] (kg/m^2)	23.8±5.1	25±5.2	-0.924	0.180
Interdialytic weight gain (kg)	3.3±1.3	3.3±1.4	-0.056	0.478
Haemoglobin[a] (gm/dl)	9±1.7	9.5±2.6	-0.804	0.2
Albumin[a] (gm/dl)	3.8±0.3	3.9±0.4	-1.217	0.1
Sodium[a] (mEq/L)	134.3±3	135±3	-0.923	0.2
Potassium[b] (mEq/L)	5.1 (4.6,5.7)	5.6 (4.5,6.1)	-0.689	0.356
Bicarbonate[a] (mEq/L)	20.6±3.8	18.1±5	2.2	0.016*
Calcium[a] (mg/dL)	8.7±0.8	9.1±2.1	-0.971	0.2
Phosphorous[a] (mg/dL)	5.6±1.7	4.3±1.4	1.21	0.001*

Note. [a]−Mean ±Standard deviation, independent t test was used; [b]−Median (25^{th} and 75^{th} Quartile), Mann Whitney U test was used; *BMI- Body mass index; *Statistically significant at 5 % level of significance.
Source: Authors.

The comparison of blood pressure (BP) parameters between groups is detailed in table 3. The number of dippers was 5/31 (16.1 %), non-dippers were 20/31 (64.5 %), and reverse dippers were 6/31 (19.3 %) in the ABPM arm. All baseline BP parameters were found to be similar in both groups. However, in the post-assessment, statistically significant differences were observed in mean systolic blood pressure (140 ± 12.7 vs. 151 ± 17.6, P=0.006), diastolic blood pressure (84 ± 6.2 vs. 89 ± 8.6, P=0.011) and mean arterial pressure (106 ± 7 vs. 110 ± 8.4, P=0.046) between the two groups. The prevalence of resistant hypertension between the groups is shown in table 3. In the ABPM group, a statistically significant reduction in hypertension was observed between baseline and the 3-month assessment (61.2 % vs. 35.5 %).

Table 3. Comparison of blood pressure parameters between groups (at baseline and after 3 months)

BP parameters		Group A	Group B	t value	P value
SBP (mmHg)	Baseline	159±22	155±19.4	1.142	0.451
	3 Months	140±12.7	151±17.6	-2.882	0.006*
DBP (mmHg)	Baseline	92±7.6	91±9.2	0.467	0.643
	3 Months	84±6.2	89±8.6	-2.626	0.011*
MAP (mmHg	Baseline	114±10.8	113±10.6	0.368	0.714
	3 Months	106±7	110±8.4	-2.037	0.046*
PP (mmHg)	Baseline	72±19.5	71±17.8	0.211	0.834

Table 3. Comparison of blood pressure parameters between groups (at baseline and after 3 months)

BP parameters		Group A	Group B	t value	P value
	3 Months	68±9.8	70±13.9	-0.655	0.515
HR	Baseline	86±3.3	85±2.6	1.325	0.19
(beats/min)	3 Months	84±2.8	83±3.3	1.287	0.203

Note. *Statistically significant at 5 % level of significance. **Source:** Authors.

Figure 1 displays the variation of blood pressure between the two groups at baseline and at 3 months. Figure 2 displays the distribution of daytime and night-time ambulatory blood pressure monitoring (ABPM) data. Daytime systolic blood pressure (SBP) averaged 160 ± 25.6 mmHg, exceeding night-time SBP of 120 ± 9.4 mmHg. Similarly, daytime diastolic blood pressure (DBP) was higher than night-time values, with averages of 96 ± 9.3 mmHg and 90 ± 11.9 mmHg, respectively. Heart rate (HR) was 87 ± 24.7 beats per minute (bpm) during the day and 81 ± 13.1 bpm at night. Similarly, at the 3-month follow-up, the daytime BP parameters exceeded night-time values.

Table 4 shows that at baseline, hypertension prevalence was similar between Group A (61.2 %) and Group B (64.5 %) (P=0.807). After three months, Group A showed a significant reduction in hypertension to 35.5 %, compared with 58 % in Group B (P=0.002). Within Group A, this reduction was statistically significant (P=0.041), whereas Group B showed no significant change (P=0.628). This indicates that the intervention in Group A was more effective in reducing hypertension among CKD patients on haemodialysis.

Table 4. Comparison of hypertension between groups (baseline and 3 months)

HTN	Group A	Group B	Chi-square value	P value
Baseline	19 (61.2 %)	20 (64.5 %)	0.061	0.807
3 Months	12 (35.5 %)	16 (58 %)	2.042	0.002*
Chi-square value	3.265	0.721		
P value	0.041*	0.628		

Note. *Statistically significant at 5 % level of significance. **Source:** Authors.

Discussion

Hypertension (HTN) is a critical cardiovascular risk factor in patients with chronic kidney disease (CKD), contributing to long-term morbidity and mortality [14]. Ambulatory blood

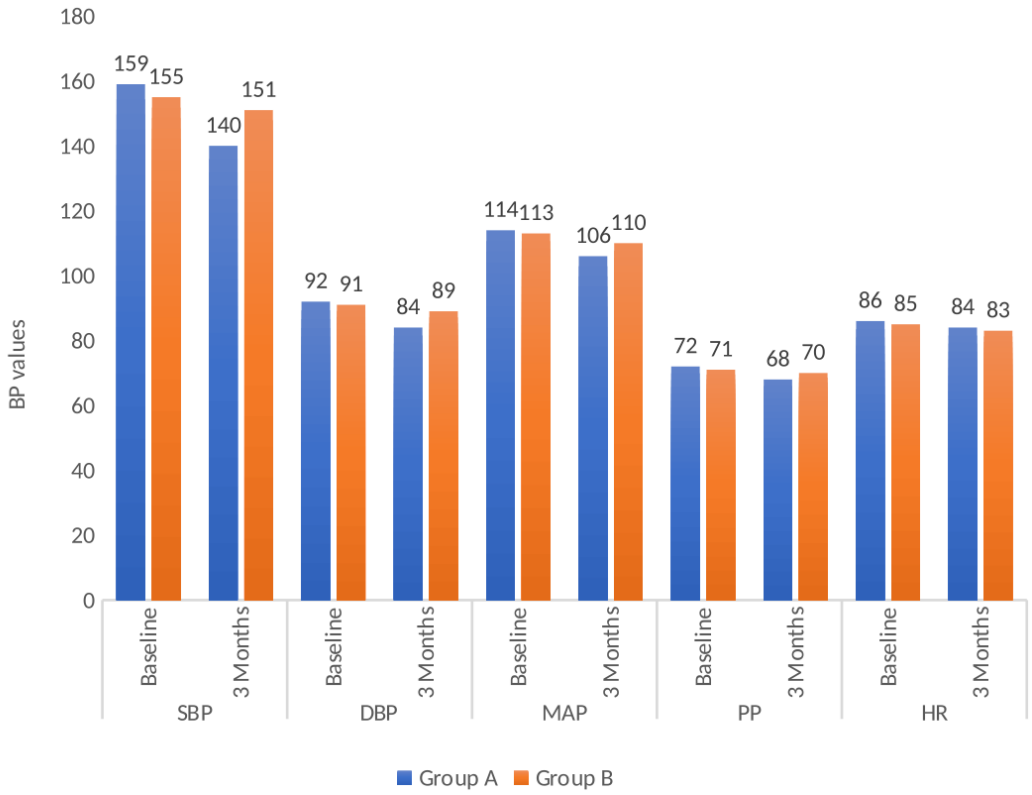

Figure 1. Graphical representation of blood pressure parameters between groups (at baseline and after 3 months)

Note. *SBP: Systolic blood pressure; DBP: Diastolic blood pressure; MAP: Mean arterial pressure; PP: Pulse pressure; HR: Heart rate.
Source: Authors.

pressure monitoring (ABPM) is recognized as the gold standard for assessing hypertension, with established prognostic importance in the general hypertensive population [15, 16]. This study aimed to evaluate the efficacy of adjunct ABPM in achieving optimal blood pressure (BP) control among patients undergoing twice-weekly maintenance haemodialysis.

A key finding of our study was the substantial improvement in BP control in the experimental group with ABPM. This highlights ABPM's superiority over conventional office-based measurements in capturing nuanced BP fluctuations, which are particularly crucial for CKD patients who experience circadian BP variability. These findings align with those of Huang et al. in Japan, who also reported the benefits of ABPM in managing BP in similar patient populations [17].

At baseline, BP parameters were similar between both groups. However, significant differences emerged post-intervention at 3 months, particularly in SBP, DBP, and MAP, with

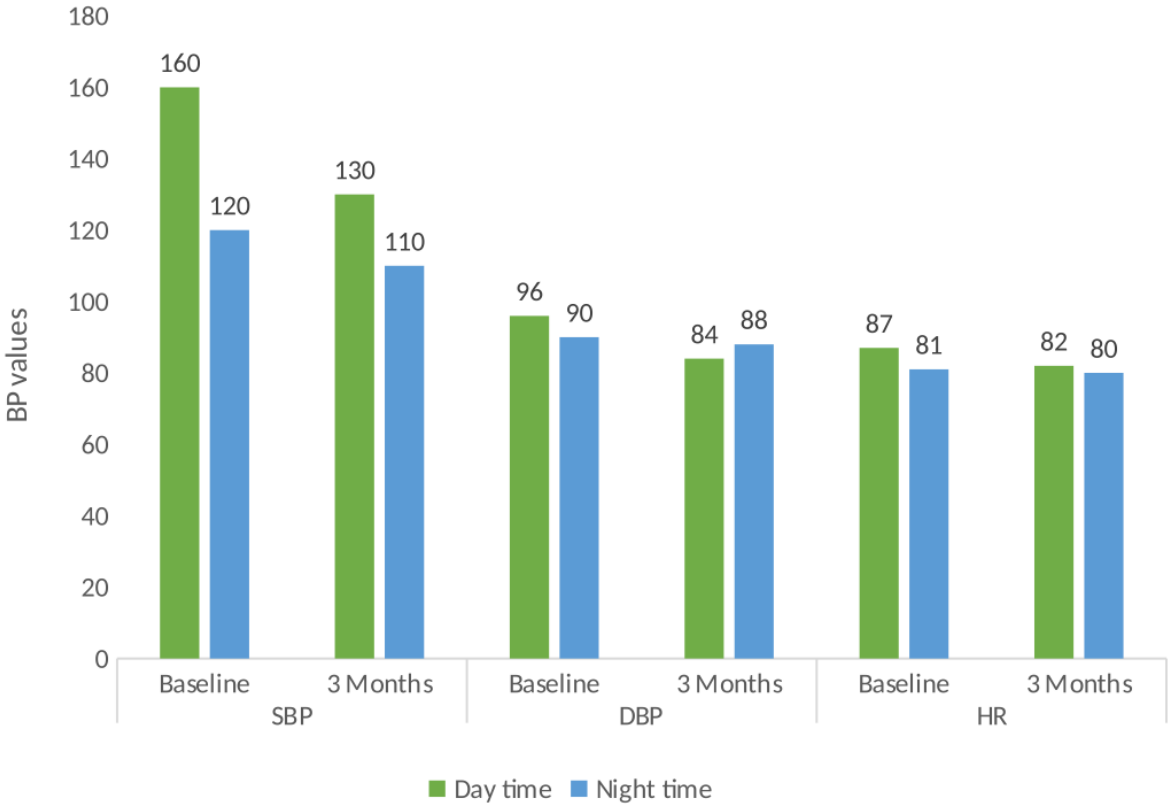

Figure 2. The distribution of daytime and night-time ambulatory blood pressure monitoring (ABPM) data

Source: Authors.

lower values noted in the ABPM group. Nocturnal dipping, observed via ABPM, typically shows nighttime BP 10 %-20 % lower than daytime BP in over 50 % of patients [18–20]. The ABPM data indicate elevated daytime SBP and DBP but an unusually elevated nighttime heart rate, suggesting an altered circadian rhythm in the haemodialysis population. This discrepancy highlights the importance of ABPM over home blood pressure monitoring (HBPM) or office BP measurements for accurate nocturnal BP assessment.

Cunha et al. also found ABPM measurements similar to ours, though with slightly lower mean 24-hour BP values, highlighting possible variations due to differences in patient demographics, ethnicity, sample sizes, comorbidities, or BP measurement protocols [21].

This study is unique in enrolling twice-weekly haemodialysis patients, contrary to the usual practice pattern worldwide. The strength of this study lies in the fact that the enrolled patients were reasonably matched in baseline characteristics and underwent twice-weekly haemodialysis with adequate URR, which is itself a notable novelty. The correct classification

of hypertensives by the initial ABPM (hidden nocturnal non-dippers, reverse dippers, and masked hypertension) after study enrollment enabled the clinician to correctly dose the anti-hypertensives, adjust their frequency, and employ long-acting antihypertensives during the 3-month period. This intervention, based on the initial ABPM assessment, resulted in better-controlled SBP and MAP at the end of 3 months in the ABPM group.

The clinical implications of ABPM-guided therapy for CKD patients on haemodialysis are profound. ABPM facilitates precise tailoring of antihypertensive regimens and dialysis protocols, enabling healthcare providers to optimize BP control and reduce cardiovascular risks effectively [13,22,23]. Interventions based on ABPM values, such as adjustments in dry weight, dosage reduction of antihypertensive drugs, and modifications in medication regimens, were implemented in a timely manner, contributing to optimal BP control in the study subjects [22,23]. This study highlights the inadequacy of routine BP monitoring alone in capturing the full spectrum of BP variability in CKD patients.

Limitations

The relatively small sample size and single-center setting may limit the generalizability of our findings. Additionally, the short follow-up period precluded the assessment of long-term outcomes of ABPM-guided therapy. Cardiovascular outcomes and mortality benefits could not be assessed due to the short follow-up period. The study showed improved BP control in the ABPM group; however, repeated ABPM would have strengthened the conclusion. The current findings support its utility as an adjunct at baseline but do not establish the sufficiency of a single ABPM assessment over time. This study did not examine the impact of thrice-weekly haemodialysis versus twice-weekly haemodialysis on blood pressure control; only dialysis adequacy was taken into consideration while enrolling the patients.

Conclusion

Our study emphasizes the importance of ABPM in enhancing personalized blood pressure management among CKD patients undergoing haemodialysis. By providing a detailed understanding of blood pressure dynamics, ABPM facilitates more effective therapeutic interventions, ultimately improving patient care and outcomes. The higher pulse pressure and heart rate observed in the ABPM group suggest increased arterial stiffness and sympathetic activation, respectively, highlighting ABPM's crucial role in detecting these dynamics and tailoring hypertension management.

Authors contribution

Rishabh Gupta, Gerry George Mathew, Varadharajan Jayaprakash and Arunkumar Asokan were responsible for conceptualization, data curation, research, writing (original manuscript), writing (revising and editing), methodology, software, validation and revising, and editing of the manuscript.

Ethical statement

Written informed consent of all study participants was obtained prior to the study. This study was approved by the SRM Medical College Institutional Ethics Committee (SRMIEC-ST0723-1229) on 16/10/2023.

Conflict of interest

None.

Financial statement

There was no financial grant for this project.

Use of artificial intelligence (AI)

The authors declare that they did not use artificial intelligence in the preparation or writing of this article.

Data availability statement

The data for substantiating the findings of this study are available with the corresponding author and can be made available on request.

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