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Impact of 24-hour Ambulatory Blood Pressure Monitoring on Early Neurological Outcomes in Acute Stroke: A Prospective Observational Study

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ABSTRACT

Background and Objective: The role of blood pressure (BP) fluctuations during the acute phase of stroke remains controversial. This study aimed to assess the circadian pattern of BP using 24-hour ambulatory blood pressure monitoring (ABPM) in acute stroke patients and analyze its association with short-term neurological outcomes.

Materials and Methods:A total of 108 patients with acute ischemic or hemorrhagic stroke, presenting within 24 hours of symptom onset, were enrolled. Initial BP readings were recorded using three supine measurements at 5-minute intervals, and the average was noted. ABPM was conducted on day 1, capturing various BP parameters over 24 hours. Functional status was assessed at admission using the Modified Rankin Scale (mRS), repeated on day 6 and at 1-month follow-up. BP patterns—dipper, nondipper, and reverse dipper—were identified and correlated with neurological recovery.

Results:Most patients exhibited a nondipping BP pattern, followed by reverse dippers and dippers. Elevated mean 24-hour systolic BP (SBP), daytime SBP, and nighttime SBP were significantly associated with unfavorable functional outcomes (mRS 4–6) at both day 6 and 1 month. Higher initial and day 6 casual SBP and diastolic BP (DBP) were also predictive of worse prognosis at 1 month.

Conclusion:In acute stroke patients, elevated 24-hour, daytime, and nighttime SBP values—especially in nondipping profiles—are strongly correlated with poor short-term neurological outcomes. ABPM may be a valuable tool in prognostication and early risk stratification in stroke care.

Keywords: *Ambulatory blood pressure monitoring, acute stroke, circadian rhythm, systolic blood pressure, neurological outcome, Modified Rankin Scale, nondipper pattern*

1. INTRODUCTION

Cerebral ischemia occurs when there is a cessation or reduction in blood flow lasting longer than several seconds. Infarction or death of brain tissue occurs if this cessation of blood flow lasts for more than a few minutes. If the resulting neurologic signs and symptoms last for >24 hours or brain infarction is demonstrated, a stroke is said tohave occurred. Elevated BP during an acute ischemic stroke acts like a double-edged sword. It may either be advantageous by improving cerebral perfusion to the ischemic tissue or more damaging by exacerbating edema and hemorrhagic transformation of the ischemic tissue.As a matter of common practice, most blood pressure (BP) recordings are done in clinical setups, either on an outpatient or in patient basis. However, home BP reading and average 24-hour ambulatory BP readings are usually lower than BPs measured in the clinic. Besides, ambulatory BP recordings provide multiple readings throughout the day and night, thereby offering a more complete assessment of the state or extent of hypertension than what can be achieved by a limited number of home BP measurements. Ambulatory BP monitoring (ABPM) can provide information on three things: an estimate of the mean BP level, the diurnal rhythm of BP, and BP variability. Additionally, it records nocturnal BPs, which are beyond the scope of other routine methods of intermittent BP monitoring. Monitors usually use the oscillometric technique. They are designed and programmed to take readings every 15–30 minutes throughout the day and night. Nocturnal BP readings are generally found to be 10–20% lower than daytime BP readings, a phenomenon referred to asa "dip." An attenuated nighttime BP "dip" can lead to a risk of both cardiovascular and cerebrovascular diseases.

In the present world scenario, where the incidence of hypertension and, consequently, the incidence of both cardiovascular and cerebrovascular diseases are increasing at a rate significant enough to raise global concerns, very few studies are actually being conducted world wide relating the two quintessential entities, especially with continuous BP monitoring in a setting where there has been a stroke. Hence, this study was designed with the aim to evaluate the pattern of 24-hour BP in acute stroke and its relation with short-term neurological outcome. Objectives of our study were to study the circadian variation of 24-hour BP in patients with acute stroke, to study the relationship between 24-hour BP and short-term (6 daysand 1 month) neurological outcome after stroke, and to determine if the BP on the 6th day of stroke has any effect on neurological outcome at 1 month post stroke.

2. MATERIALS AND METHODS

Study Design

Prospective study.

Study Area

Muzaffarnagar Medical College, Muzaffarnagar

Study Population

Patients admitted within 24 hours of acute stroke (both ischemic and hemorrhagic) were included in the study.

Sample Size

A total of one hundred eight (108) patients were enrolled in the study.

Study Duration

January 2024 to June 2024.

Inclusion Criteria

• Subjects with documented acute stroke within 24 hours prior to admission.

Exclusion Criteria

• Patients who had a transient ischemic attack or other causes leading to acute neurological deficit.

• Patients with atrial fibrillation.

• Patients who received antiarrhythmic drugs or any other agents that could influence the sympathetic and autonomic nervous system during the first 24-hour BP measurements.

• Patients with inaccurate 24-hour BPM.

A detailed neurological examination was done for all patients admitted with acute stroke within 24 hours of the event to assess their neurological status. On admission, three casual supine BP readings were measured at 5-minute intervals, and the mean value was taken. ABPM was done onday 1, and all the BP variables were recorded. On the day of admission, the functional status of all cases was assessed using the Modified Rankin Scale (MRS 0-6). On day 6, three casual BP readings were taken again, and MRS was done. The 24-hour BP profile and neurological outcome were correlated on day 1 and day 6. On follow-up at 1 month, all the patients were examined thoroughly, and MRS was done to reassess the functional status post-stroke.

Statistical Analysis

We used SPSS.23 for performing statistical analyses. The unpaired Student's t-test was used to assess continuous variables. Assessment of categorical variables was done using the Chi-squared test. We considered a p-value < 0.05 as significant.

3. RESULTS AND OBSERVATIONS

The mean age of the study subjects was 65.57 ± 13.91 years. With an increasing trend of age, the incidence of stroke was found to increase, with the highest incidence seen in those older than 70 years and the lowest in those aged 40 years or younger. Seventy-one point three percent of the study subjects were male. Ninety point seven percent (98/108) of the study population suffered from ischemic stroke, whereas nine percent (10/108) had hemorrhagic stroke. Twenty point four percent (20/98) of the subjects with ischemic stroke and sixty percent (6/10) of those with hemorrhagic stroke had a history of taking antihypertensive medicines prior to admission and were therefore known hypertensives. The relationship between the known history of hypertension and the type of stroke was found to be statistically significant [odds ratio (OR) 5.85, 95% confidence interval (CI): 1.51–22.73, p-value: 0.012]. The mean values of mean 24-hour systolic BP (SBP) (164.85 ± 13.11 mm Hg vs 150.45 ± 20.80 mm Hg, p-value: 0.001) and mean daytime SBP (161.31 ± 13.52 mm Hg vs 150.39 ± 19.95 mm Hg, p-value: 0.011) were significantly higher among patients with a history of antihypertensive use. No significant difference was found between the mean values of mean 24-hour diastolic BP (DBP), mean daytime DBP, and mean nighttime SBP and DBP across the two groups. The mean casual SBP as well as DBP of subjects with hemorrhagic stroke on day 1 were significantly higher than those of subjects with ischemic stroke. The mean 24-hour SBP and DBP values, mean daytime SBP and DBP values, and mean nighttime SBP and DBP values of subjects with hemorrhagic stroke were all significantly higher than those of subjects with ischemic stroke. The mean casual SBP and DBP values of subjects with hemorrhagic stroke on day 6 were also significantly higher than those of subjects with ischemic stroke (Table 1).

Table 1: Comparison of mean of BP values between ischemic and hemorrhagic stroke

Parameter	*Type of stroke*	*BP [mean ± standard deviation (SD)]*	*p-value*
Mean casual SBP day 1	Hemorrhagic	188.70 ± 12.24	<0.001
	Ischemic	154.96 ± 15.95	
Mean casual DBP day 1	Hemorrhagic	103.50 ± 8.14	<0.001
	Ischemic	85.09 ± 7.65	
Mean 24 hours SBP	Hemorrhagic	172.00 ± 19.32	0.003
	Ischemic	152.07 ± 19.38	
Mean 24 hours DBP	Hemorrhagic	95.60 ± 7.47	0.009
	Ischemic	85.97 ± 11.12	
Mean daytime SBP	Hemorrhagic	169.20 ± 22.74	0.004
	Ischemic	151.37 ± 18.05	
Mean daytime DBP	Hemorrhagic	97.40 ± 14.84	0.004
	Ischemic	86.15 ± 11.04	
Mean nighttime SBP	Hemorrhagic	171.00 ± 28.06	<0.001
	Ischemic	142.94 ± 21.81	
Mean nighttime DBP	Hemorrhagic	95.60 ± 13.39	<0.001
	Ischemic	79.16 ± 13.45	
Mean casual SBP day 6	Hemorrhagic	176.10 ± 8.14	<0.001
	Ischemic	140.67 ± 14.35	
Mean casual DBP day 6	Hemorrhagic	93.80 ± 5.16	<0.001
	Ischemic	79.64 ± 6.81	

Of the study population, 28.7% (31/108) were dippers, 53.7% (58/108) were nondippers, and 17.6% (19/108) were reverse dippers. Of the subjects with hemorrhagic stroke, 30% (3/10) were nondippers, 70% (7/10) were reverse dippers, and none were dippers. Among the subjects with ischemic stroke, 56.12% (55/98) were nondippers, 12.25% (12/98) were reverse dippers, and 31.63% (31/98) showed nocturnal dipping of BP. A statistically significant relationship was found between the status of nocturnal BP drop and the type of stroke incurred (p-value: < 0.001).

Seventy-seven point four two percent (24/31) of the dippers had a favorable outcome (MRS 0–3) at day 6, compared to sixty-five point five two percent (38/58) of the nondippers and fifty-two point six three percent (10/19) of the reverse dippers. However, one hundred percent of the dippers showed a favorable outcome at 1 month, compared to ninety-eight point two eight percent (57/58) of the nondippers and seventy-eight point nine five percent (15/19) of the reverse dippers. Using the Chi-squared test in a 3 × 2 contingency table, this relationship between dipping status and neurological outcome was found to be statistically significant at 1 month but not at day 6 of the stroke (Table 2).

Table 2: Relationship between dipping status and neurological outcome

Timing	*Dipping status*	*0–3*	*4–6*	*p-value*
Day 6 of stroke	Dipper	77.42% (24/31)	22.58% (7/31)	0.189
	Nondipper	65.52% (38/58)	34.48% (20/58)	
	Reverse dipper	52.63% (10/19)	47.37% (9/19)	
1 month post stroke	Dipper	100.0% (31/31)	0% (0/31)	0.001
	Nondipper	98.28% (57/58)	1.72% (1/58)	
	Reverse dipper	78.95% (15/19)	21.05% (4/19)	

It was observed that higher mean values of 24-hour SBP, mean daytime SBP, and mean nighttime SBP were all significantly associated with poorer MRS scores (4–6) both at day 6 and 1 month. Similarly, a higher mean value of casual SBP readings obtained on day 1 of stroke adversely affected the outcome in terms of MRS scores both at day 6 and 1 month. Although a higher mean value of casual DBP readings obtained on day 1 of stroke also adversely affected the outcome in terms of MRS scores both at day 6 and 1 month, the same was not true for the association of MRS scores with mean DBP readings obtained by ABPM. It was also observed that the mean values of both casual SBP and DBP readings obtained on day 6 of stroke adversely affected the outcome in terms of MRS scores at 1 month (Table 3).

Table 3: Relationship between mean BP values and neurological outcome

Parameter	MRS scores day 6	BP (mean ± SD) mm Hg	p-value	MRS scores 1 month	BP (mean ± SD) mm Hg	p-value
Mean of mean 24 hours SBP	0–3	149.90 ± 19.77	0.003	0–3	153.03 ± 19.96	0.037
	4–6	161.94 ± 18.66		4–6	172.20 ± 16.25	
Mean of mean 24 hours DBP	0–3	85.44 ± 10.25	0.062	0–3	86.58 ± 11.13	0.241
	4–6	89.69 ± 12.49		4–6	92.60 ± 11.78	
Mean of mean daytime SBP	0–3	149.07 ± 18.01	0.002	0–3	152.22 ± 19.00	0.049
	4–6	160.92 ± 19.09		4–6	169.40 ± 15.23	
Mean of mean daytime DBP	0–3	86.61 ± 10.74	0.471	0–3	87.28 ± 12.04	0.730
	4–6	88.36 ± 13.84		4–6	85.97 ± 11.12	
Mean of mean nighttime SBP	0–3	140.90 ± 22.84	0.004	0–3	144.06 ± 22.80	0.003
	4–6	154.81 ± 23.13		4–6	176.00 ± 25.10	
Mean of mean nighttime DBP	0–3	79.43 ± 13.38	0.196	0–3	80.23 ± 14.03	0.134
	4–6	83.19 ± 15.66		4–6	90.00 ± 16.49	
Mean casual SBP day 1	0–3	153.19 ± 16.93	<0.001	0–3	156.82 ± 17.75	0.001
	4–6	167.86 ± 17.61		4–6	184.20 ± 12.83	
Mean casual DBP day 1	0–3	84.56 ± 8.72	<0.001	0–3	86.28 ± 9.05	0.009
	4–6	91.28 ± 9.05		4–6	97.40 ± 10.14	
Mean casual SBP day 6	0–3	139.10 ± 15.14	<0.001	0–3	142.85 ± 16.61	0.002
	4–6	153.67 ± 17.40		4–6	166.60 ± 17.04	
Mean casual DBP day 6	0–3	79.04 ± 6.99	<0.001	0–3	80.49 ± 7.46	0.004
	4–6	84.78 ± 8.10		4–6	90.60 ± 10.04	

To determine whether there was any statistically significant difference in the mean ABPM readings between the MRS scores at day 1, day 6, and 1 month of the stroke, one-way analysis of variance (ANOVA) was used. It was found that the difference between the mean 24-hour SBP, mean daytime SBP, and mean nighttime SBP readings among the various MRS score categories at day 6 was statistically significant. However, at 1 month, a statistically significant difference was found only between the mean values of 24-hour SBP and nighttime SBP, but not the mean daytime SBP. The mean DBP readings showed no significant difference across the various MRS score categories at either day 6 or 1 month of stroke. Table 4 depict these findings.

Table 4: Results obtained from ANOVA showing significant differences between the means of ABPM readings across MRS score categories

Parameter	MRS scores day 6		MRS scores 1 month	
	F	p-value	F	p-value
Mean of mean 24 hours SBP	3.795	0.006	2.984	0.015
Mean of mean 24 hours DBP	1.203	0.314	1.155	0.337
Mean of mean daytime SBP	3.918	0.005	2.192	0.061
Mean of mean daytime DBP	0.788	0.536	0.414	0.838
Mean of mean nighttime SBP	4.245	0.003	5.205	<0.001
Mean of mean nighttime DBP	1.159	0.333	1.088	0.372

4. DISCUSSION

In our study, most of the subjects had suffered an ischemic stroke, while a minority had suffered a hemorrhagic stroke. The majority of cases with ischemic stroke were not known hypertensives, whereas most of those with hemorrhagic stroke were known hypertensives and were using antihypertensive medication. This is similar to the study by Vemmos et al.,[1] where it was observed that hypertension had a significantly higher prevalence among patients suffering from intracranial hemorrhage (75.98%) compared to those suffering from ischemic stroke (63.5%).

It is common to observe BP variability during an acute stroke. In our study, the mean casual SBP and DBP of subjects with hemorrhagic stroke on day 1 as well as day 6 were significantly higher than those of subjects with ischemic stroke. Similarly, the mean 24-hour BP as well as both daytime and nighttime BP values of subjects with hemorrhagic stroke measured with ABPM were all significantly higher than those of subjects with ischemic stroke. Celik et al.[2] in his study also observed a significantly higher initial SBP and DBP in the hemorrhagic group than in the ischemic group ($p < 0.01$).

While the mean values of mean 24-hour SBP and mean daytime SBP were significantly higher among the patients with known history of hypertension, no such relationship was found between the mean values of mean 24-hour DBP, mean daytime DBP, and mean nighttime SBP and DBP across the two groups. Ntaios et al.[3] in contrast, saw that patients without hypertensive disease and with a low BP at the beginning seemed to benefit from an increase in BP, and that in patients with hypertension, initial BP and its subsequent changes had a lesser influence on clinical outcome.

Blood pressure alterations after an acute stroke, especially a reduction in the day-night difference of BP and a transient elevation in BP following a stroke, have been mentioned in multiple studies.[4] A significant reduction in circadian BP variation after stroke was initially reported by Sander and Klingelhofer.[5] In our study, also in accordance with that, the majority of subjects were nondippers, followed by dippers. Reverse dippers accounted for a small proportion of study subjects.

Most of the subjects with hemorrhagic stroke were reverse dippers, followed by nondippers, and none of them were dippers. Among the subjects with ischemic stroke, the majority were either nondippers or reverse dippers, but 31.63% of subjects did show nocturnal dipping of BP. Our study shows a statistically significant relationship (p-value: < 0.001) between the status of nocturnal BP drop and the type of stroke incurred. Yamamoto et al.[6] in his study, proposed that apart from the association between reduced nighttime BP decline and the extent and type of stroke, the nocturnal BP dip could also determine the specific location of the intracranial lesion.

Higher mean values of mean 24-hour SBP, mean daytime SBP, and mean nighttime SBP were significantly associated with poor neurological outcome. However, the mean of mean DBP values on ABPM did not show a significant relation with neurological outcome on MRS scoring. Robinson et al.[7] studied the prognostic significance of 24-hour BP compared to casual BP in its ability to predict mortality at 30 days, neurological outcome, and dependency. He observed a significantly higher casual and 24-hour SBP and DBP at admission in patients who were eventually found to have a poorer outcome at 1 month after an acute stroke in terms of mortality, dependency, or neurological deterioration, on single-variable logistic regression analysis. In contrast to our study, no association was found between changes in SBP during the 1st week following stroke, short-term functional status, and long-term mortality of stroke patients by Weiss et al.[8] Even higher casual SBP and DBP at day 1 and day 6 were significantly associated with poor neurological outcome (MRS score 4–6). Similar observations were made by Abboud et al.,[9] Vemmos et al.,[1] and Ahmed et al.[10] However, baseline mean arterial pressure was not found to be associated with poor ischemic stroke outcome as observed by Aslanyan et al.[11] In the same study, variables describing the course of BP over the first 2.5 days had a marked and independent relationship with 1 and 3 months. Similarly, Yong et al. observed that a higher baseline SBP or DBP was associated with a favorable outcome after stroke.[12]

Analysis of variance showed that there was a statistically significant difference between the mean of mean 24-hour SBP, mean daytime SBP, and mean nighttime SBP readings among the various MRS score categories at day 6. However, at 1 month, a statistically significant difference was found only between the means of mean 24-hour SBP and mean nighttime SBP, but not the mean daytime SBP. The mean DBP readings, however, showed no significant difference across the various MRS score categories either at day 6 or 1 month after stroke.

5. CONCLUSION

A failure of either the nocturnal dip in BP or a rise in the same was found to be significantly common in persons with both types of stroke. Higher mean 24-hour SBP, mean daytime SBP, and mean nighttime SBP were associated with poor short-term neurological outcome. The mean of mean 24-hour SBP, mean daytime SBP, and mean nighttime SBP readings significantly varied across the increasing MRS scores at day 6 of stroke, while at 1 month only the mean of mean 24-hour SBP and mean nighttime SBP showed similar variance. Higher casual SBP and DBP readings were also associated with a poor short-term neurological outcome.

A cutoff for ABPM values predicting poor short-term neurological outcome could be obtained from the study. It should be mentioned, however, that some subjects with lacunar infarcts were included, which could have altered the value of ambulatory DBP readings as a predictor of poor neurological outcome. Sampling errors could have reduced the number of hemorrhagic strokes in the study population.

We therefore conclude that routine use of ABPM in day-to-day clinical practice in the setting of acute stroke may be undertaken for the purpose of risk stratification after the event. The cutoff values of SBP readings obtained from ABPM can help in predicting the short-term neurological outcome in patients with acute stroke

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