Effects of Carotid Stenting on Nocturnal Nondipping Phenomenon

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Background: It is well known that nondipper blood pressure (BP) pattern is associated with an increased cardiovascular risk in hypertensive patients. The aim of this study is to observe whether carotid artery stent (CAS) procedure returns nondipper BP pattern to dipper pattern in hypertensive patients. *Methods:* Ambulatory BP monitorization (ABPM) was performed in 152 hypertensive patients who underwent CAS procedure 1 day before, and 1 day and 1 year after the procedure. BP monitorization of patients was classified as dipper and nondipper. BP parameters 1 year after CAS procedure were compared with preprocedure parameters. *Results:* According to baseline ambulatory BP follow-ups, a total of 152 hypertensive patients with 122 (80%) nondippers and 30 (20%) dippers were enrolled in this study. According to ABPM results 1 year after CAS procedure, 78 patients (64%) who had nondipper pattern at first transformed into dipper pattern and 44 patients (36%) remained to be nondippers. Moreover, 1 year after CAS procedure, 18 patients (60%) who had dipper pattern at first transformed into nondipper pattern and 12 patients (40%) remained as dippers. When BP follow-up values at 1 year after CAS procedure were compared with BP readings before the procedure, 78 patients (51%) who were nondipper before the procedure transformed into dipper pattern ($P \leq .01$), whereas 44 patients (29%) with nondipper pattern remained to be nondippers ($P = .01$). Twelve patients (7.9%) who had dipper pattern remained to have dipper pattern ($P = .768$). Eighteen patients who had dipper pattern (12%) transformed into nondipper pattern after the procedure ($P < .01$). The total number of nondipper pattern patients before CAS procedure was 80.3% (122 patients), whereas this percentage dropped to 40.8% (62 patients) after the CAS procedure ($P < .01$). *Conclusions:* During 1-year follow-up after CAS procedure, nondipper BP pattern transforms into dipper pattern. This result might be attributed to the contributory effect of CAS procedure to long-term cardiovascular protection. **Key Words:** Ambulatory blood pressure monitoring—carotid artery stenting—carotid sinus baroreceptor—dipper—nondipper—stroke.

Carotid artery stenosis is situated in bifurcation of carotid artery which also involves the initial portion of internal carotid artery. This anatomic localization also contains abundant carotid baroreceptors. Baroreceptors located in adventitia are sensitive to pressure. Stimulation of baroreceptors with stent inhibits sympathetic neurons located in nucleus tractus solitarius. This inhibition decreases sympathetic tonus on peripheral vessels and

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therefore, it decreases systemic blood pressure (BP). After carotid artery stent (CAS) procedure, BP readings are at lower levels because of the chronic baroreceptor pressure by stent.[1]

Arterial hypertension is a modifiable risk factor listed as a cause of both arterial hypertension and etiology of ischemic or hemorrhagic stroke.[2] Arterial BP is affected by the interactions between neuro-humoral, behavioral, and environmental factors. Arterial BP exhibits a circadian type of rhythm. This refers to the daily variation of BP that is generally higher during the day than at night.[3,4] The introduction of ambulatory BP monitoring (ABPM) techniques has provided unique information about the diurnal variations of BP.[5,6] In normal subjects, BP decreases during sleep by 10% to 20% and increases promptly on waking, a phenomenon known as the dipping pattern.[7] The underlying mechanisms responsible for blunted nocturnal fall in BP are not completely understood. In hypertensive patients, this normal diurnal BP variation pattern is usually preserved, particularly when there is no target organ damage. However, a variety of abnormal diurnal variation patterns have been described in which the nocturnal fall of BP may be more than 20% (extreme dippers), less than 10% (nondippers), or even reversed (reverse dippers).

Patients with nondipper BP pattern have increased sympathetic activity. This group of patients have increased risk of cardiovascular disease.[8,9] Stimulation of carotid baroreceptors by stent inhibits sympathetic system.

The aim of this study is to observe whether nondipper BP patterns of mean systemic BP return to dipper pattern in hypertensive patients after CAS procedure as assessed with 24-hour BP Holter recordings during long-term follow-up.

Materials and Methods

Study Population

A total of 189 hypertensive patients who underwent CAS procedure and followed for 1 year between December 2010 and December 2013 were enrolled in this study. Of 189 patients, 37 were excluded from the study because of various reasons. Among these patients, 6 had their antihypertensive drug group changed. Antihypertensive drug dose or number was changed in 14 patients. Ambulatory Holter recording was not complete in 7 patients. Two patients had ischemic stroke after CAS during follow-up, 1 patient had gastrointestinal bleeding, 1 had myocardial infarction, 1 developed renal failure, and 1 patient deceased after cardiac surgery. Three patients had stent restenosis in follow-up Doppler ultrasound. Seven patients were lost to follow-up because of variety of reasons.

Local ethical committee approval was obtained before patient enrollment. The following were the inclusion criteria for patients to receive CAS treatment: more than 50% stenosis in carotid artery as assessed by angiography in a symptomatic patient, or more than 70% stenosis in carotid artery as assessed by angiography in an asymptomatic patient. Patients who had heart failure, severe pulmonary insufficiency, renal failure, serious arrhythmia, cerebral bleeding, resistant hypertension, thyroid hormone disorder, sleeping problems, and complications during CAS procedure; patients who were noncompliant to their medications; patients who had their antihypertensive medication, dose, or number changed in follow-up; patients who had extreme dipper or reverse dipper BP patterns in 24-hour BP Holter recording; and patients who used vasodilator drugs other than antihypertensives were excluded from the study.

The percentages of stenosis in carotid artery were calculated according to NASCET formula. Symptomatic patients had ischemic cerebrovascular event with or without sequela, transient ischemic attack, or amaurosis fugax during the past 6 months. Restenosis was described as instant flow rate 224 cm/sn or more in Doppler ultrasound or 50% or more stenosis in computerized tomography angiography scan.

Patients were accepted as hypertensive if the following were present: (1) current use of antihypertensive drugs; (2) presence of resting systolic BP of 140 mm Hg and/or diastolic BP of 90 mm Hg; and (3) an average 24-hour BP value above 130/80 mm Hg.

Ambulatory Blood Pressure Monitoring

Patients were taken to CAS procedure after BP regulation was obtained. BPs of patients were followed with 24-hour ABPM the day before, the day after, and 1 year after the procedure. BP patterns before CAS procedure were compared with BP patterns 1 year after the procedure. Twenty-four-hour BP monitorization after CAS procedure was used for hemodynamic follow-up. ABPM studies were carried out using a Mobil-O-Graph NG, I.E.M. GmbH (Stolberg, Germany) monitoring device. BP was measured by oscillometric method, and the first hour was discarded from analysis. BP readings were obtained automatically at 15-minute intervals during the day, and at 30-minute intervals during the night. Recordings were accepted only if more than 85% of the raw data was valid. The absolute decrease and the percentage of the decrease in nighttime systolic BP versus daytime systolic BP were calculated in all subjects. Time in bed was defined based on a patient-kept diary that documented the exact times of getting into and getting out of bed. The average BP for this time in bed was calculated from the ambulatory monitoring data (and was termed nighttime BP). Daytime BP was defined as the average BP during the remainder of this 24-hour period. Mean BP was calculated as the diastolic pressure plus