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Hypertension

SPRINT

# Effect of Intensive Versus Standard Blood Pressure Control on Stroke Subtypes

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**ABSTRACT:** In the SPRINT (Systolic Blood Pressure Intervention Trial), the number of strokes did not differ significantly by treatment group. However, stroke subtypes have heterogeneous causes that could respond differently to intensive blood pressure control. SPRINT participants (N=9361) were randomized to target systolic blood pressures of <120 mm Hg (intensive treatment) compared with <140 mm Hg (standard treatment). We compared incident hemorrhage, cardiac embolism, large- and small-vessel infarctions across treatment arms. Participants randomized to the intensive arm had mean systolic blood pressures of 121.4 mm Hg in the intensive arm (N=4678) and 136.2 mm Hg in the standard arm (N=4683) at one year. Sixty-nine strokes occurred in the intensive arm and 78 in the standard arm when SPRINT was stopped. The breakdown of stroke subtypes across treatment arms included hemorrhagic (intensive treatment, n=6, standard treatment, n=7) and ischemic stroke subtypes (large artery atherosclerosis: intensive treatment n=11, standard treatment, n=13; cardiac embolism: intensive treatment n=11, standard treatment n=15; small artery occlusion: intensive treatment n=8, standard treatment n=8; other ischemic stroke: intensive treatment n=3, standard treatment n=1). Fewer strokes occurred among participants without prior cardiovascular disease in the intensive (n=43) than the standard arm (n=61), but the difference did not reach predefined statistical significance level of 0.05 (*P*=0.09). The interaction between baseline cardiovascular risk factor status and treatment arm on stroke risk did not reach significance (*P*=0.05). Similar numbers of stroke subtypes occurred in the intensive BP control and standard control arms of SPRINT. **(*Hypertension*.2021;77:1391-1398. DOI: 10.1161/HYPERTENSIONAHA.120.16027.)**

**Key Words:** atherosclerosis ■ blood pressure ■ hemorrhagic stroke ■ hypertension ■ ischemic stroke



Stroke is the fifth leading cause of death in the United States and the leading cause of adult disability. The estimated annual cost of stroke is expected to increase by $240 billion by 2030.[1] The most recent American Heart Association/American Stroke Association statement on the primary prevention of stroke states, "The relationship between blood pressure (BP) and stroke risk is strong, continuous, graded, consistent, independent, predictive, and etiologically significant".[2] Observational studies show a benefit of lower BP down to 115/75 for both men and women aged 40 to 89 years in relation to risk of first fatal or nonfatal stroke.[3,4] Multiple randomized controlled trials have also shown a benefit of moderate BP lowering in primary stroke prevention, and some have shown a benefit of more intensive BP lowering to various targets as well, but the issue of what BP target is optimal for stroke prevention remains unsettled.[5]

The SPRINT (Systolic Blood Pressure Intervention Trial) randomized 9361 participants with an increased cardiovascular risk, but without diabetes or a history of stroke, to a systolic BP target of <120 mm Hg (intensive treatment) or a target of <140 mm Hg (standard treatment) and was stopped early when the combined primary end point was reached. The combined primary outcome favored the intensive BP arm, with significantly fewer fatal and nonfatal major cardiovascular events (including stroke) and death from any cause. However, although fewer strokes occurred in the intensive arm, only 147 stroke events had accrued by study

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For Sources of Funding and Disclosures, see page 1397.

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## Novelty and Significance

### What Is New?

- SPRINT (Systolic Blood Pressure Intervention Trial) provided a unique opportunity to compare intensive blood pressure control to standard blood pressure control in relation to the risk of hemorrhagic and ischemic stroke and their subtypes.

### What Is Relevant?

- Hypertension is a strong risk factor for stroke through its effects on the heart and systemic arteries.
- Intensive blood pressure lowering could halt the deleterious effects of hypertension and lower the risk of stroke or cause brain ischemia in the setting of long-standing hypertension.

### Summary

The number of hemorrhagic and ischemic stroke subtypes were similar across the intensive and standard blood pressure arms of SPRINT. Intensive blood pressure lowering was not associated with an elevated risk of cerebral small vessel strokes compared with standard control.

## Nonstandard Abbreviation and Acronyms

| | |
|---|---|
| **ACCORD** | Action to Control Cardiovascular Risk in Diabetes |
| **BP** | blood pressure |
| **CCS** | Causative Classification System |
| **CE** | cardiac embolism |
| **HOPE** | Heart Outcomes Prevention Evaluation |
| **SPRINT** | Systolic Blood Pressure Intervention Trial |
| **SPS3** | Secondary Prevention of Small Subcortical Strokes |

termination.[6] Since stroke is a broad term referring to events caused by multiple mechanisms, most of them modifiable by treatment of hypertension, it is important to examine the effect of intensive BP lowering on different stroke subtypes to better understand the mechanisms that link hypertension with different types of brain damage. BP-lowering appears to be beneficial for preventing both ischemic and hemorrhagic stroke, but only limited data are available on the effects of BP treatment on different types of stroke, especially ischemic stroke subtypes.[3,4] Cerebral small vessel disease due to hypertensive vasculopathy can manifest as small subcortical (ie, lacunar) infarctions and intraparenchymal hemorrhages and may be the most direct link between high BP and stroke. Hypertension also leads to heart disease, including myocardial infarction, nonvalvular atrial fibrillation, and heart failure predisposing to cardiac embolism (CE) that results in stroke. Large vessel atherosclerosis leads to local thrombosis or artery to artery embolism. Given the established links between hypertension and small vessel stroke, and the reductions in heart failure and cardiovascular mortality due to intensive BP lowering seen in SPRINT, we hypothesized that intensive BP lowering would also result in fewer strokes attributable to cerebral small vessel disease or those attributable to a cardiogenic mechanism.

## METHODS

The data that support the findings of this study are available from the corresponding author upon reasonable request.

### Study Design

Stroke subtyping was a prespecified outcome. The design and cardiovascular outcome results for SPRINT have been described previously.[6,7] Adults 50 years of age or older with systolic BP between 130 and 180 mm Hg at screening were enrolled. Participants were at elevated cardiovascular risk, defined as either having chronic kidney disease with an estimated glomerular filtration rate of 20 to <60 mL/(min·1.73 $m^2$), a 10-year Framingham cardiovascular disease risk ≥15%, or being 75 years of age or older. Exclusions included having diabetes, a history of prior stroke or dementia, or living in a nursing home. Enrolled participants were randomly assigned to either an intensive treatment strategy with a systolic BP goal of <120 mm Hg or a standard treatment strategy with a systolic BP goal of <140 mm Hg. SPRINT was funded by the National Heart, Lung, and Blood Institute and co-funded by the National Institute of Diabetes and Digestive and Kidney Diseases, the National Institute of Neurological Disorders and Stroke, and the National Institute on Aging. An independent data and safety monitoring board monitored unblinded trial results and safety events. The study was approved by the institutional review board at each participating study site (URL: https://www.clinicaltrials.gov; Unique identifier: NCT01206062).

### Stroke Adjudication and Subtyping

Randomization was stratified by clinical site and participants, and study personnel were aware of study-group assignments, but outcome adjudicators were blinded and did not adjudicate cases from their home networks. Medical records and electrocardiograms were obtained for documentation of events and whenever clinical site staff became aware of a stroke, the approved protocol was followed to obtain information on the

event.[7] A member of the Stroke Subcommittee (C. Wright) of the Morbidity and Mortality Committee of SPRINT adjudicated stroke subtypes using the Causative Classification System (CCS), a standardized, automated, evidence-based, and web-based subtype classification system adapted for use in SPRINT as specified in the design and rationale publication.[7,8] The CCS generated 5 mutually exclusive categories for each case: large artery atherosclerosis (supra-aortic), CE, small artery occlusion, other uncommon causes, and undetermined causes.[8–10] The undetermined category was further divided into cryptogenic, multiple competing causes, and incomplete evaluation.[8,9] We also stratified CE into major-CE and minor-CE where major CE denotes cardio-embolic sources with high potential to cause a stroke such as atrial fibrillation, and minor CE indicates sources with a low- or uncertain potential to cause a stroke such as mitral annulus calcification (1–4).[8–11] Finally, we generated an additional cryptogenic group that also included low- or uncertain-risk cardiac sources. The CCS software stratified each CCS category into 3 confidence levels as evident, probable, and possible depending on the level of causal evidence. Because of the small number of strokes, we determined the effects of the intervention by aggregating the confidence levels.

### Statistical Analysis

We compared the number of participants with stroke types and subtypes across treatment arms using $\chi^2$ tests or Fisher exact tests (for expected cell counts <5). The 3 major stroke types were hemorrhagic, ischemic, and unknown. Hemorrhagic strokes were classified as subarachnoid, intraparenchymal, or other. We then used Cox proportional hazard models stratified by clinical site to estimate hazard ratios and 95% CIs comparing stroke rates across prespecified subgroups using tests of interaction with significance defined as Hommel-adjusted alpha levels smaller than 0.05.[12]

## RESULTS

Characteristics of the SPRINT participants are shown in Table 1 and were well balanced across BP treatment arms. Of 9361 participants randomized to intensive (N=4678) or standard (N=4683) BP control, 69 participants in the intensive arm versus 78 participants in the standard arm had strokes during a mean follow-up of 3.33 years (Figure 1). There was no significant difference in the number of strokes overall by treatment arm.[6] Likewise, baseline cardiovascular risk factor status did not significantly modify the effect of the intervention. However, for those having no prior history of cardiovascular disease at baseline, results favored intensive BP control, but this did not reach significance (*P*=0.05, Figure 2).

Hemorrhagic and ischemic strokes and their subtypes across treatment arms are shown in Table 2. There were 32 events that could not be classified as to type, and 5 with incomplete stroke evaluations that prevented subtype classification. Roughly 70% of strokes were ischemic, with cryptogenic (31%) and cardioembolic (25%) being the most common subtypes. The treatment effects of intensive BP were consistent for the different stroke subtypes with generally fewer strokes in the intensive arm regardless of subtype. Likewise, treatment effects were similar across arms when the undetermined category was broken into subgroups, when the CE category was stratified into major and minor, and when minor CE was combined with the cryptogenic category. The number of ischemic and hemorrhagic stroke subtypes was similar across age (<75 versus ≥75 years), sex, and race/ethnic strata (*P*=0.05, Figure 2).

## DISCUSSION

In this prespecified analysis of SPRINT data, intensive BP lowering resulted in similar numbers, types, and subtypes of strokes compared with standard BP control during follow-up. The numbers of hemorrhagic and ischemic stroke subtypes were similar across arms.

As indicated in the primary outcomes report, intensive BP control in SPRINT participants reduced the risk of heart failure and death from cardiovascular causes, with a nonsignificant decrease in the number of myocardial infarctions as well.[6] Given these findings, a lower risk of ischemic strokes caused by CE in the intensive BP control group than the standard control group might be expected. However, the number of stroke events was small, and SPRINT was not powered to detect these differences. Although the anticipated difference in systolic BP between randomized arms (>10 mm Hg) was achieved, it is possible a difference in strokes may have been observed if greater systolic BP differences across arms had been attained.

Hypertension is a major risk factor for small vessel arteriopathies that lead to end-organ damage affecting the brain, heart, kidney, and eye.[13–16] Intensive BP lowering could limit such damage in patients with hypertension, thereby protecting against stroke. In the SPS3 (Secondary Prevention of Small Subcortical Strokes) trial that enrolled participants with recent lacunar strokes who were thus at greater risk of stroke than those in SPRINT, maintaining systolic BP below 130 mm Hg compared with 130 to 139 mm Hg resulted in significantly fewer incident intraparenchymal hemorrhages but not new ischemic strokes.[17] Since intraparenchymal hemorrhage often results in severe morbidity and mortality, it is notable that intensive BP lowering did not result in fewer hemorrhages compared with standard control in the current study.

Intensive lowering of BP in patients with longstanding hypertension could also place some organs at risk of ischemia should BP be lowered too aggressively. In the brain, longstanding hypertension has been hypothesized to require greater BPs to maintain adequate cerebral perfusion pressures and avoid ischemia due to a rightward shift in the autoregulatory curve.[18] Data are limited, but a small study showed cerebral hemodynamic responses were

**Table 1. Baseline Clinical Characteristics by Treatment Arm**

| Characteristic | Intensive treatment (N=4678) | Standard treatment (N=4683) |
|---|---|---|
| Criterion for increased cardiovascular risk, n (%) | | |
| Age ≥75 y | 1317 (28.2%) | 1319 (28.2%) |
| Chronic kidney disease | 1329 (28.5%) | 1316 (28.3%) |
| Cardiovascular disease, n (%) | 940 (20.1%) | 937 (20.0%) |
| Clinical | 779 (16.7%) | 783 (16.7%) |
| Subclinical | 247 (5.28%) | 246 (5.3%) |
| Framingham 10-y cardiovascular disease risk score ≥15% | 3556 (76.0%) | 3547 (75.7%) |
| Female sex, n (%) | 1684 (36.0%) | 1648 (35.2%) |
| Age, y | | |
| Overall | 67.9±9.4 | 67.9±9.5 |
| Among those ≥75 y of age | 79.8±3.9 | 79.9±4.1 |
| Race or ethnic group, n (%) | | |
| Non-Hispanic Black | 1379 (29.5%) | 1423 (30.4%) |
| Hispanic | 503 (10.8%) | 481 (10.3%) |
| Non-Hispanic White | 2698 (57.7%) | 2701 (57.7%) |
| Other | 98 (2.1%) | 78 (1.7%) |
| Black race* | 1454 (31.1%) | 1493 (31.9%) |
| Baseline blood pressure, mm Hg | | |
| Systolic | 139.7±15.8 | 139.7±15.4 |
| Diastolic | 78.2±11.9 | 78.0±12.0 |
| Distribution of systolic blood pressure, n (%) | | |
| ≤132 mm Hg | 1583 (33.8%) | 1553 (33.2%) |
| >132 to <145 mm Hg | 1489 (31.8%) | 1549 (33.1%) |
| ≥145 mm Hg | 1606 (34.3%) | 1581 (33.8%) |
| Serum creatinine, mg/dL | 1.07±0.34 | 1.08±0.34 |
| Estimated GFR, mL/(min·1.73 m$^2$) | | |
| Among all participants | 71.8±20.7 | 71.7±20.5 |
| Among those with estimated GFR ≥60 mL/(min·1.73 m$^2$) | 81.3±15.5 | 81.1±15.5 |
| Among those with estimated GFR <60 mL/(min·1.73 m$^2$) | 47.8±9.5 | 47.9±9.5 |
| Ratio of urinary albumin (mg) to creatinine (g) | 44.1±178.7 | 41.1±152.9 |
| Fasting total cholesterol, mg/dL | 190.2±41.4 | 190.0±40.9 |
| Fasting HDL cholesterol, mg/dL | 52.9±14.3 | 52.8±14.6 |
| Fasting total triglycerides, mg/dL | 124.8±85.8 | 127.1±95.0 |
| Fasting plasma glucose, mg/dL | 98.8±13.7 | 98.8±13.4 |
| Statin use, n/total n (%) | 1978/4646 (42.6%)† | 2076/4640 (44.7%)† |
| Aspirin use, n/total n (%) | 2406/4662 (51.6%)† | 2350/4666 (50.4%)† |
| Smoking status, n (%) | | |
| Never smoked | 2051 (43.8%) | 2072 (44.2%) |
| Former smoker | 1977 (42.3%) | 1996 (42.6%) |
| Current smoker | 639 (13.7%) | 601 (12.8%) |
| Missing data | 11 (0.2%) | 14 (0.3%) |
| Atrial fibrillation, n/total n (%) | 390/4661 (8.4%)† | 364/4666 (7.8%)† |
| Framingham 10-y CVD risk score, % | 24.8±12.6 | 24.8±12.5 |
| Body mass index | 29.9±5.8 | 29.8±5.7 |
| Antihypertensive medications prescribed, no/patient | 1.8±1.0 | 1.8±1.0 |
| Not using antihypertensive agents, n (%) | 432 (9.2%) | 450 (9.6%) |

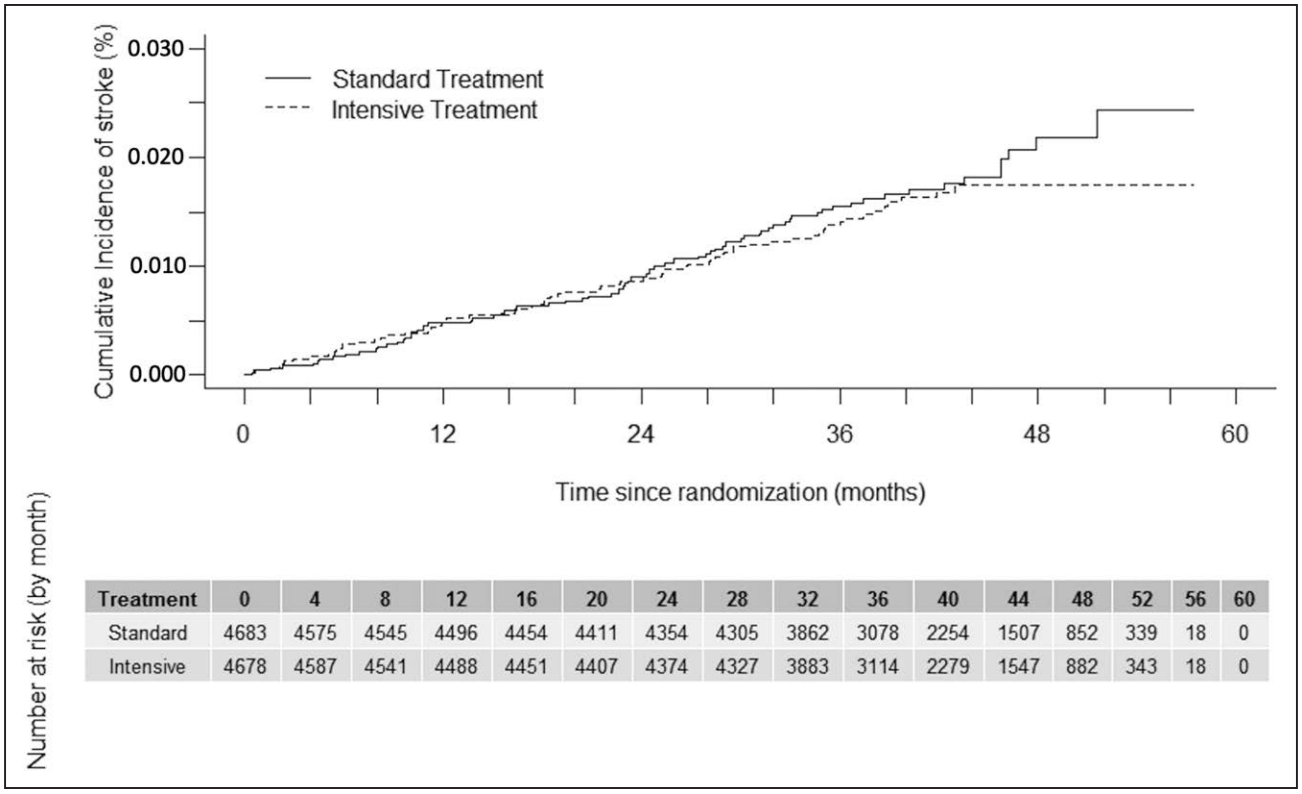
CVD indicates cardiovascular disease; HDL, high density lipoprotein; and GFR, glomerular filtration rate. Black race includes Hispanic Black and Black as part of a multiracial identification.

Black race includes Hispanic Black and Black as part of a multiracial identification.

†Denominator smaller than overall treatment arm totals due to missing data.

stable acutely and up to four months later after initiating treatment of mild and moderate hypertension.[19] In SPRINT, intensive BP lowering also did not increase the risk of stroke subtypes usually attributable to cerebral small vessel disease such as intracerebral hemorrhage and lacunar stroke. These findings are consistent with the ACCORD trial (Action to Control Cardiovascular Risk in Diabetes) where intensive BP control targeted below 130 mm Hg significantly lowered stroke risk and with pooled data from SPRINT and ACCORD that showed no increase in stroke risk from intensive BP lowering.[20,21] Further, the SPRINT MIND study found intensive BP control lowered the risk of mild cognitive impairment and the combined outcome of mild cognitive impairment and probable dementia.[22] Intensive BP control did not prevent probable dementia alone (the primary outcome) compared with standard BP control, but there were only about half as many dementia as mild cognitive impairment events due to early termination.

In the current study, we did not find a notable difference between treatment arms in the number of hemorrhagic or ischemic strokes usually attributed to small vessel arteriopathies, namely intraparenchymal hemorrhages and lacunar infarctions. However, the SPRINT-MIND MRI sub-study showed that participants in the intensive BP treatment arm had less progression of white matter hyperintensities than those in the standard arm and that this effect did not differ across various subgroups (those with and without prior cardiovascular disease; those with and without a history of orthostatic hypertension; those older versus younger than 75; and across baseline BP levels).[23] Since there was reason to be concerned about the possible detrimental effects of intensive BP control in all of these subgroups, these findings are reassuring. In addition, since only 22 strokes in the small vessel subtype categories occurred during follow-up, lack of concordance with the MRI sub-study findings could be attributable to the small number of events. In addition, white matter hyperintensities are areas of extracellular water detected on T2-weighted MRI sequences and, though strongly associated with small vessel damage, are nonspecific.




| Treatment | 0 | 4 | 8 | 12 | 16 | 20 | 24 | 28 | 32 | 36 | 40 | 44 | 48 | 52 | 56 | 60 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Standard | 4683 | 4575 | 4545 | 4496 | 4454 | 4411 | 4354 | 4305 | 3862 | 3078 | 2254 | 1507 | 852 | 339 | 18 | 0 |
| Intensive | 4678 | 4587 | 4541 | 4488 | 4451 | 4407 | 4374 | 4327 | 3883 | 3114 | 2279 | 1547 | 882 | 343 | 18 | 0 |

**Figure 1. Cumulative incidence plot of stroke events by treatment arm in SPRINT (Systolic Blood Pressure Intervention Trial).**
The cumulative incidence of stroke events (*y* axis) in each SPRINT study arm is plotted for the number of participants at risk by month of follow-up (*x* axis).



SPRINT was not designed to examine hypertensive medication class effects, and the small number of ischemic strokes does not allow for a meaningful analysis of the potential class effects of different BP agents. Some classes have been posited to provide additional benefits beyond BP lowering. For example, the HOPE

| Subgroup | Intensive Treatment | Standard Treatment | Hazard Ratio | Int P |
|---|---|---|---|---|
| Overall | 69/4678 (1.5) | 78/4683 (1.7) | 0.89 (0.64, 1.23) | |
| No Prior CKD | 40/3326 (1.2) | 49/3336 (1.5) | 0.82 (0.54, 1.25) | 0.60 |
| Prior CKD | 29/1329 (2.2) | 29/1316 (2.2) | 0.98 (0.58, 1.66) | |
| Age < 75 | 38/3361 (1.1) | 40/3364 (1.2) | 0.97 (0.62, 1.51) | 0.53 |
| Age >= 75 | 31/1317 (2.4) | 38/1319 (2.9) | 0.75 (0.46, 1.22) | |
| Male | 38/2994 (1.3) | 53/3035 (1.7) | 0.72 (0.47, 1.09) | 0.13 |
| Female | 31/1684 (1.8) | 25/1648 (1.5) | 1.24 (0.73, 2.11) | |
| Non-Black | 54/3224 (1.7) | 54/3190 (1.7) | 0.95 (0.65, 1.39) | 0.33 |
| Black | 15/1454 (1.0) | 24/1493 (1.6) | 0.65 (0.33, 1.22) | |
| No Prior CVD | 43/3738 (1.2) | 61/3746 (1.6) | 0.71 (0.48, 1.05) | 0.05 |
| Prior CVD | 26/940 (2.8) | 17/937 (1.8) | 1.56 (0.84, 2.96) | |
| SBP <= 132 | 17/1583 (1.1) | 19/1553 (1.2) | 0.85 (0.44, 1.65) | 0.45 |
| 132 < SBP < 145 | 22/1489 (1.5) | 19/1549 (1.2) | 1.24 (0.66, 2.33) | |
| SBP >= 145 | 30/1606 (1.9) | 40/1581 (2.5) | 0.76 (0.47, 1.22) | |

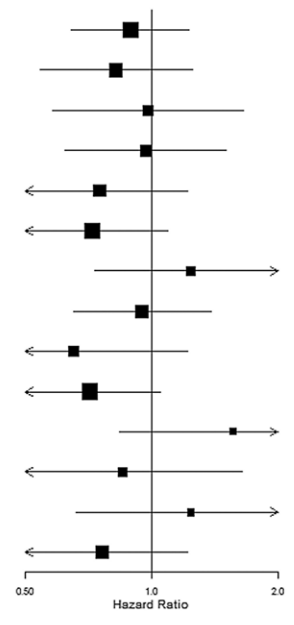



**Figure 2. Forest plot of stroke outcome by subgroups.**
The forest plot for the groups of interest. Note that all interactions between covariate and treatment arm are nonsignificant for stroke as an outcome at the <0.05 significance level. CKD, chronic kidney disease; CVD, cardiovascular disease; and SBP, systolic blood pressure.

**Table 2. Stroke Subtypes in the SPRINT**

| Stroke Outcome | Overall (N=9361) | Intensive (N=4678) | Standard (N=4683) | *P* value |
|---|---|---|---|---|
| Absolute overall, n (%) | 147 (1.6) | 69 (1.5) | 78 (1.7) | 0.51 |
| Hemorrhagic stroke, n (%) | 13 (0.1) | 6 (0.1) | 7 (0.2) | 1.00 |
| Subarachnoid hemorrhage | 3 (0.0) | 2 (0.0) | 1 (0.0) | 0.65* |
| Intraparenchymal hemorrhage | 6 (0.1) | 3 (0.1) | 3 (0.1) | 1.00* |
| Other hemorrhage | 4 (0.0) | 1 (0.0) | 3 (0.1) | 0.62* |
| Ischemic stroke, n (%) | 102 (1.1) | 48 (1.0) | 54 (1.2) | 0.62 |
| Large artery atherosclerosis | 24 (0.3) | 11 (0.2) | 13 (0.3) | 0.84 |
| Cardiac embolism | 26 (0.3) | 11 (0.2) | 15 (0.3) | 0.56 |
| Major cardiac embolism | 13 (0.1) | 5 (0.1) | 8 (0.2) | 0.58 |
| Minor cardiac embolism | 13 (0.1) | 6 (0.1) | 7 (0.2) | 1.00 |
| Small artery occlusion | 16 (0.2) | 8 (0.2) | 8 (0.2) | 1.00 |
| Other uncommon causes | 4 (0.0) | 3 (0.1) | 1 (0.0) | 0.38* |
| Undetermined cause | 32 (0.3) | 15 (0.3) | 17 (0.4) | 0.86 |
| Unknown: cryptogenic embolism | 19 (0.2) | 8 (0.2) | 11 (0.2) | 0.65 |
| Multiple competing causes | 8 (0.1) | 4 (0.1) | 4 (0.1) | 1.00* |
| Incomplete evaluation | 5 (0.1) | 3 (0.1) | 2 (0.0) | 0.69* |
| Unknown stroke type, n (%) | 32 (0.3) | 15 (0.3) | 17 (0.4) | 0.86 |

SPRINT indicates Systolic Blood Pressure Intervention Trial.
*Denotes Fisher exact test.

trial (Heart Outcomes Prevention Evaluation) showed a benefit to adding ramipril to standard BP treatment for both ischemic and hemorrhagic stroke, and the Systolic Hypertension in the Elderly Program showed a benefit of chlorthalidone versus placebo for various stroke subtypes.[24,25]

The CCS was used for ischemic stroke subtype classification in this study and differs from conventional systems in that it is fully rule- and evidence-based as an algorithm, using objective criteria to assign stroke causes into easily replicable subtypes.[26] The reported $\kappa$ values for CCS range between 0.75 and 0.90 depending on the data source, number of cases, and number of raters.[8–11] In contrast, reports from independent investigators demonstrate only moderate reliability with $\kappa$ values ranging between 0.42 and 0.54 for conventional etiologic classification systems.[27–31] Likewise, CCS provides higher discriminative validity compared with other classification systems, because the CCS generates more distinct subtypes with discrete clinical, genetic, and prognostic features.[26,32] However, the ability of etiologic classification, regardless of the system used, to unambiguously assign the cause of stroke is limited because of the absence of pathology data. This problem is greater for the category of CE as this category includes several abnormalities with discrete embolic potential. The CCS provided the flexibility to examine the effect of intensive BP reduction across a wide range of causes generated based on the strength of causal evidence. For instance, we stratified cardiac sources into high risk and low- or uncertain-risk CE. Likewise, we generated a new cryptogenic category that included low- or uncertain-risk cardiac pathologies. We found that the intervention effect was similar across such categories, suggesting that the etiologic mechanism of stroke is not a strong determinant of benefit from intensive BP reduction, with the caveat noted above about the small number of strokes in each category.

## Limitations

This study was not powered to detect differences in stroke subtypes. The generalizability of these findings is limited to people with higher cardiovascular risk than the general population due to the enrollment criteria that excluded those with diabetes mellitus, prior stroke, and nursing home residents. A single adjudicator did the ischemic stroke subtype classifications using the CCS system, and intrarater reliability was not measured during the adjudication process.

In summary, we found similar numbers of stroke subtypes in the intensive BP control and standard control arms of SPRINT.

## Perspectives

Hypertension leads to stroke through heart disease, especially atrial cardiopathy and atrial fibrillation, as well as large vessel atherosclerosis and small vessel arteriolosclerosis. In addition, longstanding hypertension may place the brain at elevated risk of ischemia if BP is treated aggressively. It is important to understand if intensive BP control affects the risk of certain types of stroke. In SPRINT, intensive BP control did not reduce the risk of stroke overall, but the study was stopped early and the number of strokes was

small. Different kinds of damage lead to diverse types of stroke, and intensive BP control could affect them in different ways. In this study, we compared the effect of intensive BP control to standard BP control on the risk of different types of stroke and found that hemorrhagic and ischemic subtypes were similar across treatment arms and neither BP control strategy showed greater benefits or harms. Future well-powered stroke studies are needed to understand the role of intensive BP control on different types of stroke in those at high risk of cardiovascular disease and longstanding hypertension.

## ARTICLE INFORMATION

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