9. Pannier JL, Leusen I: Circulation to the brain of the rat during acute
11. Pannier JL, Wayne J, Demester G, Leusen I: Effect of non-
12. Reneman R, Wellens D, Jageneau A, Styven L: Vertebral and
14. Wellens D, Wouters L, Nijkamp F, De Jong W: Distribution of the
blood flow supplied by the vertebral artery in rats: anatomical,
15. Chungcharoen D, De Burgh Daly M, Neil E, Schweitzer A: The
effect of carotid occlusion upon the intrasinal pressure with spe-
cial reference to vascular communications between the carotid and
vertebral circulations in the dog, cat and rabbit. J Physiol 117: 56–76, 1952
occlusion. Resting and hypercapnic flow related to collateral pat-
18. Levine S, Payan H: Effects of ischemia and other procedures on the
19. Kahn K: The natural course of experimental cerebral infarction in

**Sympathetic Nerve Activity: A Link To Stroke?**

**SHIRLEY M. MUELLER, M.D., AND WILLIAM L. BLACK JR., B.A.**

**SUMMARY** Spontaneously hypertensive rats (SHR) have been shown to have an increased capacity for superior cervical sympathetic nerve activity which may protect against stroke (Mueller et al: Stroke 13: 115, 1982). Sympathetic nerve activity has never been examined in the stroke-prone substrain of SHR (SP). In this study we measured superior cervical sympathetic nerve activity during rest and during a maximal sympathetic response in SHR, SP and their normotensive controls, Wistar-Kyoto (WKY). The resting superior cervical sympathetic nerve activity of SP was significantly less than SHR (p < 0.02) but not different from WKY. During central ischemia, used to induce maximal sympathetic response, the increase in SP sympathetic nerve activity was significantly less than SHR (p < 0.001) but was not different from WKY. This diminished capacity for elevated superior cervical sympathetic nerve activity in stroke-prone SHR may relate to their increased predisposition to stroke because sympathetic hyperactivity cannot protect cerebral vessels during acute hypertension.

**HYPERTENSION** is among the important risk factors for stroke. However, it is seldom clear why one hyper-
tensive individual has a stroke and another does not. Study of animal models analogous to human essential
hypertension, the spontaneously hypertensive rat, (SHR), and the substrain of the SHR that is susceptible
to stroke, the stroke-prone SHR, may relate to their increased incidence of stroke. However, Ikeda, et al, did
not provide direct evidence to support this concept.

The purpose of this study was to directly measure superior cervical sympathetic nerve activity in SP,
SHR and their normotensive controls, Wistar-Kyoto (WKY), during resting conditions and during a maxi-
mal sympathetic stimulus. The change in sympathetic nerve activity between these two conditions could
provide direct evidence to support this concept. The change in sympathetic nerve activity may protect against these changes. Such information would further enhance our understanding of stroke.

**Methods**

Twenty-three male animals 16–26 weeks of age were used for this study. They were allowed free ac-
cess to standard Purina rat chow and water. Nine of the animals were SP (original stock obtained from Carl
Hansen at the National Institute of Health), eight were SHR and six were WKY (Charles Rivers, Boston,
MA). All rats were anesthetized with sodium pento-
barbital (50 mg/kg i.p.). Each rat was artificially venti-
lated with a respirator and paralyzed with gallamine
triethiodide (6 mg/kg). The left femoral artery was cathe
erized with thin walled PE-50 tubing filled with
heparinized saline for measurement of blood pressure. The left superior cervical trunk, caudal to the superior cervical ganglia, was then separated from the vagus and aortic depressor nerves. The sympathetic nerve fibers were stripped of their connective tissue covering using 40X magnification (Karl Zeiss, model 64051).

The sympathetic fibers were then suspended from bipolar stainless steel electrodes and bathed in a pool of mineral oil to prevent drying. The nerve activity was detected with an AC differential preamplifier (Grass Instruments, model P-15) with a time constant of three milliseconds. The amplified nerve signals were displaced on a Tektronix oscilloscope (model 5103) for visualization. These signals were further amplified using a high gain operational amplifier, then rectified using a full wave rectifier circuit and integrated continuously with an RC integrator (time constant = 20 milliseconds). This integration method has been previously described by Ninomiya, et al. The signals were averaged using an RC network with a time constant of one second.

The nerve data presented in this paper is expressed as mean superior cervical sympathetic nerve activity (SNA) above noise level and is calibrated in microvolts (μV). The noise level was determined in each experiment by shorting the input electrodes and recording the noise level. This value (3 to 7 μV) was then subtracted from the raw data obtained in each experiment. The blood pressure and electroneurogram were both recorded on a Beckman type R dynograph.

Within 45 minutes after sedation, superior cervical sympathetic nerve activity was recorded during resting conditions for 15 minutes in all animals. The average sympathetic nerve activity during that period was determined and designated as resting sympathetic nerve activity. A maximal sympathetic discharge was obtained through inducing central ischemia produced by rapid hemorrhage of the animals. The blood pressure and electroneurogram were both recorded on a Beckman type R dynograph.

Results

The mean arterial pressure of the SHR and SP was significantly elevated over the WKY (SHR 191 ± 11*, SP 181 ± 6*, WKY 107 ± 6 mmHg, *p < .001) during resting conditions (Table 1). Resting superior cervical sympathetic nerve activity of SHR was significantly elevated over SP and WKY (SHR 21 ± 3*, SP 12 ± 1, WKY 10 ± 2 μV, *p < .02) (table 1).

Results

The mean arterial pressure of the SHR and SP was significantly elevated over the WKY (SHR 191 ± 11*, SP 181 ± 6*, WKY 107 ± 6 mmHg, *p < .001) during resting conditions (Table 1). Resting superior cervical sympathetic nerve activity of SHR was significantly elevated over SP and WKY (SHR 21 ± 3*, SP 12 ± 1, WKY 10 ± 2 μV, *p < .02) (table 1). SHR peak sympathetic nerve activity (during central ischemia) was significantly elevated over that of SP and WKY (SHR 250 ± 11*, SP 114 ± 12, WKY 114 ± 18, *p < .001) (fig. 1). The increase in superior cervical sympathetic nerve activity of SHR was significantly elevated over the change in SP and WKY (SHR 229 ± 10*, SP 101 ± 11, WKY 105 ± 18, *p < .001) (fig. 2).

Discussion

In this study, the capacity for sympathetic outflow of SP was similar to that of WKY and much less than SHR. One must consider the possibility that the lack of capacity for elevated sympathetic nerve activity in SP may be a contributing factor to the accelerated stroke found in these animals compared to SHR.

It has been shown that the sympathetic nerves play an important role in cerebral vascular protection during acute hypertension when the autoregulatory capacity of the cerebrovascular bed has been exceeded. This protective influence of the sympathetic nerves outside
SYMPATHETIC NERVE ACTIVITY: A LINK TO STROKE?/Mueller and Black

Figure 2. The change in sympathetic nerve activity (SNA) elicited by central ischemia in spontaneously hypertensive rats (SHR, n = 8), Wistar-Kyoto (WKY, n = 6) and stroke prone SHR (SP, n = 9). The increase in SNA in the SHR (p < 0.001) was significantly elevated over WKY and SP.

of the autoregulatory range would be expected to be attenuated in SP. Thus, although the SP rats are hypertensive like SHR, they did not appear to have the same protection of their cerebral vasculature by sympathetic nerves as SHR.

In addition to the acute protective effect of an elevation in sympathetic nerve activity on the cerebral vasculature, a chronic influence of sympathetic nerves on the vasculature has been reported that appears to be protective during profound cerebral vasodilation and blood-brain barrier disruption. It has been suggested that this long term effect is due to a "trophic" influence on smooth muscle proliferation in the vessel wall. Denervation of the sympathetic supply of several vascular beds has been shown to decrease smooth muscle mass and alter the structural integrity of the vessel. This long term "trophic" influence of sympathetic nerves on the SP vasculature might also be altered compared to SHR.

In summary, the present experiment directly demonstrated that the SP had an attenuated capacity for superior cervical sympathetic nerve activity when compared to SHR. An elevated sympathetic nerve activity to the cerebral vessels in SHR may be protective against stroke both acutely and chronically. One can conjecture that alterations in superior cervical sympathetic nerve activity, possibly genetic in origin, may contribute to stroke in selected hypertensive individuals.

Acknowledgments

The authors wish to thank Kathleen Bell for typing the manuscript and Matthew J. Mick for assisting in preliminary studies.

References

Sympathetic nerve activity: a link to stroke?
S M Mueller and W L Black, Jr

Stroke. 1985;16:73-75
doi: 10.1161/01.STR.16.1.73

Stroke is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1985 American Heart Association, Inc. All rights reserved.
Print ISSN: 0039-2499. Online ISSN: 1524-4628

The online version of this article, along with updated information and services, is located on the
World Wide Web at:
http://stroke.ahajournals.org/content/16/1/73

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in
Stroke can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office.
Once the online version of the published article for which permission is being requested is located, click Request
Permissions in the middle column of the Web page under Services. Further information about this process is
available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at:
http://www.lww.com/reprints

Subscriptions: Information about subscribing to Stroke is online at:
http://stroke.ahajournals.org//subscriptions/