Effect of an Acute Increase of the Intravascular Pressure on the Blood-Brain Barrier
A Comparison between Conscious and Anesthetized Rats

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SUMMARY Conscious rats and rats under nitrous oxide anesthesia were subjected to blood pressure elevations by injection of epinephrine, bicuculline and amphetamine. Mean arterial pressure was measured from a chronic indwelling cannula in the aorta in awake rats. The protein leakage in the brains was studied using Evans blue and 125IHSA. Conscious animals developed less blood-brain barrier dysfunction than anesthetized ones. The largest difference was obtained with amphetamine and the smallest with epinephrine. Possible explanations to the results are discussed.

IT HAS BEEN SHOWN in many studies that acute hypertension can increase the cerebral vascular permeability to protein in anesthetized animals (Johansson). In conscious rats blood-brain barrier (BBB) dysfunction has been observed in renal hypertensive rats in connection with abrupt blood pressure elevations and in angiotensin-induced acute hypertension. No comparison between the degree of extravasation in conscious and anesthetized animals has so far been reported. As some preliminary observations indicated there was a difference between conscious and anesthetized rats, the aim of the present study was to compare the pattern and degree of extravasation after a blood pressure increase induced by epinephrine, bicuculline or amphetamine. In addition to the forced dilatation that may occur in acute hypertension per se, bicuculline and amphetamine give rise to a marked vasodilatation which increases the vessel wall tension and thus the vulnerability to mechanical stress. Extensive and consistent patterns of protein extravasation are observed in the brains and the protein leakage can be completely prevented if the blood pressure is kept low.

Material and Methods

A. Conscious Rats

Male Sprague-Dawley rats (200-300 g) were used. Mean arterial pressure (MAP) was measured directly from a chronic indwelling cannula in the aorta. The cannula was implanted under barbiturate anesthesia 2 or 3 days prior to the hypertension experiments. At the same time a venous cannula was positioned in the right external jugular vein. Two ml of a 2 percent solution of Evans blue (EB) in saline • kg⁻¹, which in vivo binds to serum albumin, and 100 µCi • kg⁻¹ of ¹²⁵IHSA (human serum albumin) were injected i.v. except in the amphetamine group which received EB only. After arterial blood gas analyses, epinephrine (20 µg • kg⁻¹), bicuculline (1.2 mg • kg⁻¹) or dl-amphetamine (2.5 mg • kg⁻¹) was administered i.v. Three minutes later the rat was anesthetized with pentobarbital i.v. and the brain perfused with saline in situ for 30 seconds to rinse blood from the cerebral vessels. Predetermined parts were subjected to scintillation counting and the extravasation of ¹²⁵IHSA was expressed as 100 • (counts • min⁻¹ mg⁻¹ brain tissue)/(counts • min⁻¹ mg⁻¹ blood). The blood sample was taken immediately before starting the perfusion through the heart.

B. Anesthetized Rats

Anesthesia was induced with diethyl ether. A femoral artery and a femoral vein were cannulated, the animals were tracheotomized, immobilized with suxamethonium chloride and artificially ventilated with a mixture of 30% O₂ and 70% N₂O. The experiments were thereafter performed in the same way as in the conscious rats, i.e. the same tracers and drugs were used and perfusion through the heart was started 3 minutes after the injection of epinephrine, bicuculline or amphetamine. As preliminary experiments showed that the pressure response to epinephrine was less in the anesthetized rats, probably because the initial MAP was higher than in conscious rats, a small dose of dihydralazine (0.1-0.2 mg, sufficient to lower the blood pressure 15-25 mm Hg), was given to the rats before the injection of epinephrine. The electroencephalogram (EEG) was recorded from scalp electrodes in rats that received bicuculline. Statistical differences were evaluated with the Wilcoxon rank sum test.

Results

Initial and maximum MAP are given in table 1. The pressure increase was slightly more abrupt in conscious than in anesthetized rats after epinephrine and bicuculline, whereas no consistent difference was seen after amphetamine which in both groups resulted in a more gradual pressure increase. In conscious rats the blood pressure response to amphetamine varied considerably. (The 6 rats presented in table 1 were selected from a total of 15 rats because the pressure in-
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The brains from 5 of 6 awake rats given amphetamine (Paco2 3.5-4.1 kPa). Hyperventilation has been shown to diminish the BBB dysfunction both in hypertension per se and after amphetamine administration. However, the mild degree of hypercapnia would not be expected to completely prevent extravasation, nor can changes in blood gases explain the difference in the bicuculline group. Thus, in anesthetized and ventilated rats Paco2 decreases in the early stage of bicuculline-induced epileptic seizures whereas it increases markedly in conscious rats. (In 3 additional conscious rats subjected to repeated arterial blood gas determinations of Paco2 increased to 6.67-7.17 kPa after 60 seconds and to 10.61-11.92 kPa after 2 minutes).

Bill and Lindner have demonstrated that sym-
pathetic stimulation of the cervical sympathetic chain can prevent the BBB dysfunction and flow increase in anesthetized cats during acute hypertension. This has been confirmed by MacKenzie et al. in studies on baboons. Sympathetic stimulation can also diminish protein extravasation in rats given amphetamine or bicuculline. Thus, a difference in sympathetic tone between anesthetized and conscious animals could be one possible explanation for the present finding. However, preliminary experiments indicate that cervical sympathectomy does not, to any substantial degree, increase the protein leakage in conscious rats (Hardebo, Johansson and Edvinsson, unpublished observations). Further studies are in progress to analyze the effect of the peripheral sympathetic system as well as to evaluate the possible role of the central noradrenergic system proposed by Raichle et al. to take part in the regulation of the cerebral blood flow and vascular permeability.

References
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