JOURNAL OF PHYSIOLOGY AND PHARMACOLOGY 2000, 51, 1, 111—125

S. LIPIŃSKA

THE ROLE OF ADRENORECEPTORS IN THE REGULATION OF OXYTOCIN AND VASOPRESSIN RELEASE AFTER SUPERIOR CERVICAL GANGLIONECTOMY

Department of Physiology, Institute of Physiology and Biochemistry, Medical University of Lodz, Poland

In male rats under anaesthesia, dialysis of the venous blood from sella turcica region was carried out. Vasopressin and oxytocin content was determined in the dialysates by radioimmunoassay. The obtained results indicate that:

1. Electrical stimulation of the superior cervical ganglion causes an increase in vasopressin and oxytocin release.
2. 20 days after superior cervical ganglionectomy the vasopressin and oxytocin release increased.
3. Superior cervical ganglionectomy immediately before the dialysis evoked a several times increase in vasopressin and oxytocin release.
4. Application of α_1-blocker, prazosin, as well β-blocker, propranolol, has partially prevented the increase in vasopressin release which was found immediately after superior cervical ganglionectomy.
5. Contrary to vasopressin, the increase in oxytocin release after superior cervical ganglionectomy is completely prevented by the β- blocker, propranolol, and only partially by the α_1- blocker, prazosin.

Key words: *oxytocin, vasopressin, superior cervical ganglion, adrenergic receptors*

INTRODUCTION

Neurons of the hypothalamic supraoptic and paraventricular nuclei are known to synthesize vasopressin and oxytocin and to release these neurohormones from axon terminals in the neural lobe of the pituitary gland. These nuclei receive a rich and historically well described innervation from brainstem

The data were presented as an abstract at the XXXIII International Congress of Physiological Sciences, held in St. Petersburg (Russia) June 30 — July 5 1997, and III International Congress of Pathophysiology 28.06—3.07.1988 Lahti (Finland).

noradrenaline (NA)-containing cell groups, prompting several investigations into the role of NA of in neurohypophysial hormone release (1).

The existence of the functionally relevant peripheral noradrenergic (sympathetic) projection to the hypothalamic-pituitary axis, derived from the superior cervical ganglia (SCG), has been proposed on the basis of anatomic and physiologic studies (2, 3). Bilateral superior cervical ganglionectomy (SCGx) brought a decrease in NA (4, 5), vasopressin (5, 6) and oxytocin in the posterior pituitary lobe (7, 8).

On the neurochemical basis three phases are apparent following peripheral denervation of medial basal hypothalamus (MBH) after SCGx. After an initial phase of nerve paralysis, lasting about 10 h and reflecting in low MBH cyclic adenosine monophosphate accumulation, the anterograde (walerian) degeneration of sympathetic nerve endings starts, NA is released from degenerating nerve varicosities, and it exerts postsynaptic effects as shown by the MBH cyclic adenosine monophosphate synthesis and occupation of the cyclic adenosine monophosphate binding sites (9, 10). 24—48 h after surgery, an irreversible paralytic phase ensues, resulting some time later in a significant increase in alpha-adrenoreceptor binding in MBH membranes, as well as in pharmacological evidence of alpha-adrenergic supersensitivity of rat MBH (11). In paralytic phase 5 h after SCGx vasopressin content of the pituitary neurointermediate lobe decreases, and an increase in vasopressin release into the blood, in degenerating phase is observed (6).

Our earlier studies point to the stimulatory influence of SCG in the function of the posterior pituitary lobe, because after electric stimulation of preganglionic fibres of SCG the release of vasopressin and oxytocin release increased (12, 13, 14).

The objective of the present study is to examine how the abolished sympathetic pulsation arising from SCG influences the release of vasopressin and oxytocin, and what kind of adrenergic receptors is involved in mediating the effect of increase in vasopressin and oxytocin release during paralityc phase after SCGx.

MATERIAL AND METHODS

Animals

The experiments were performed on male rats, weighing 300—320 g, 5—9 months old F_1 generation cross-strains of male August and female Wistar, from the Institute of Oncology in Warsaw. The animals in surgical experiments were anaesthetized by an i.p. injection of a solution containing 6 mg of chloralose (Roth) and 60 mg of urethane (Flucka Ah, CH—9470 Bucks) per 100 g body weight. In chronic experiments the animals were anaesthetized by i.p. injection of hexabarbitane 80 mg/kg b.w.

Experimental protocols

Two series of experiments were performed.

In the first experiment the animals were divided into four groups: 1. control (n = 10); 2. 20 days after SCGx (n = 10); 3. immediately after SCGx (n = 8); 4. after the preganglionic fibers of SCG stimulation (n = 7).

In the second experiment, groups of 8—10 rats subjected to SCGx or control, and the animals which received the α_1-adrenergic blocker, prazosin, (Sigma, St. Louis Mo USA; 1,25 mg/kg), the β-adrenergic blocker, propranolol, (Sigma, St Louis Mo USA; 6,25 mg/kg/dose), or a combination of both drugs, as intraventricular injection in 0,2 mL of saline before dialysis were included. Applied dose of blockers did not change arterial blood pressure.

Exposure and superior cervical ganglionectomy

Care was taken to administer and to attain a surgical stage of anaesthesia and to allow a rapid recovery of the animal. The salivary glands were exposed through a ventral incision in the neck; the glands were retracted to expose through a ventral incision in the neck; the glands were retracted to expose the strap muscles and each SCG was identified at the bifurcation of the common carotid artery into its internal and external branches. The ganglia were totally removed from both sides.

Electrical stimulation of the superior cervical ganglion

Bipolar platinum electrodes were slipped under the preganglionic fibers of SCG so that the electrodes did not come into contact with adjacent tissues. Electrodes were connected to a Disa stimulator Type 13 G04. Stimulation parameters were monitored by a Cossor oscilloscope ST 509A. For stimulation of SCG monophasic electric pulses of the following parameters were applied: frequency 20 Hz, duration 3 msec, amplitude 10 V, (30 sec stimulation on and 30 sec stimulation off) for 30 min. Ipsilateral dilatation of the palpebral fissue was observed during the stimulation.

Dialysate blood sampling

In order to obtain blood dialysate samples from the vicinity of the pituitary, one polyethylene cannula was inserted into the heart end of the internal maxillary vein, and the second cannula into the maxillary vein, in the vicinity of cavernous sinus of the sella turcica. Blood was drawn from the region of *sella turcica* through the polyethylene cannula to the minidialysator with the use of the peristaltic pump. It was then returned to the organism through the cannula inserted into the heart end of the maxillary vein. At the beginning of the experiments, 2 mL of Lock solution with heparin (400 UJ/mL) was injected into the internal maxillary vein.

The whole amount of dialysing fluid was exchanged every 30 min for 2 hrs, by draining it directly into a test tube. Four 1 mL samples of dialysate were obtained this way. Before refilling the minidialysator with dialysing fluid, its cover was rinsed with Mc Ilwain-Rodnight solution. At the end of each experiment 1% solution of trypan blue was injected through a cannula inserted into the internal maxillary vein. The brains were then removed from the skull and the dye in the posterior pituitary lobes were verified under a stereomicroscope. Only these dialysate samples, which were collected from animals showing the staining of the posterior pituitary lobe, were included into the results. Staining of the posterior pituitary lobe has proved proper insertion of the cannula into the vicinity of cavernous sinus of the sella turcica, and proper blood collection.

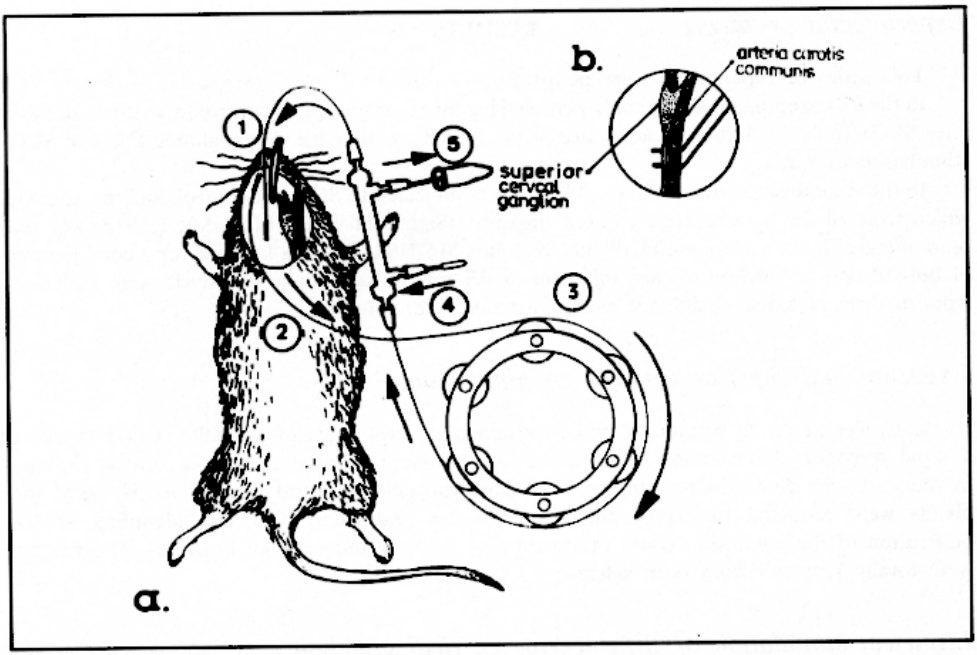

Fig. 1. Dialysis of venous blood outflowing from the cavernous sinus vicinity of the *sella turcica* in rats: a) 1 — cannula inserted into the heart end of the internal maxillary vein. 2 — cannula inserted into the *sella turcica* end of the internal maxillary vein. 3 — peristaltic pump. 4 — inflow tube for filling minidialysator housing. 5 — outflow tube for collecting dialysating medium from the minidialysator housing; b) exposed superior cervical ganglion with preganglionic nerve electrodes.

Minidialysator characteristics

Minidialysators have been manufactured according to our design by EURO-SEP-Ltd Warsaw. They have two tips for Luer's needles for connecting one side through a cannula with a vein, and the side- with a peristaltic pump. At the side of the minidialysator there are two tips for Louer's needles for the exchange of the dialysing fluid.

Minidialysators were tested in *in vitro* experiments. Inulin clearance, inulin flow and ultrafiltration were elaborated elsewhere (15). Vasopressin and oxytocin recovery for concentrations 30—24 000 pg/ mL amounted to $52 \pm 4.8\%$, and $63 \pm 5.3\%$, respectively, for vasopressin and oxytocin, irrespective of the concentration.

Radioimmunoassay of vasopressin and oxytocin

The content of vasopressin and oxytocin in dialysates were radioimmunoassayed and expressed in pg/mL (16).

Statistical analysis

Statistical analysis of results was performed with a two-way factorial analysis of variance (ANOVA) followed by Duncan's test.

RESULTS

Vasopressin and oxytocin release after superior cervical stimulation and superior cervical ganglionectomy.

The release of vasopressin and oxytocin into the dialysis fluid in control rats did not change during 180 min of the experiment. The arterial pressure measured with a mercurial manometer in femoral vein did not change either. Electric stimulation of preganglionic fibres of SCG caused a 2.5-fold increase of vasopressin release (*Fig. 2*), and a 3.5-fold increase in oxytocin release (*Fig. 3*), into the dialysing fluid in comparison to the control. SCGx immediately before dialysis, increased the release of vasopressin already in the first 30 min dialysate sample, attaining the maximal value after 60 min (16-fold increase in relation to control); during further 60 min it maintained a high level (*Fig. 2*). SCGx immediately before the dialysis, increased the release of oxytocin at its maximum (65-fold) between 150 and 180-min (*Fig. 3*). SCGx 20 days earlier

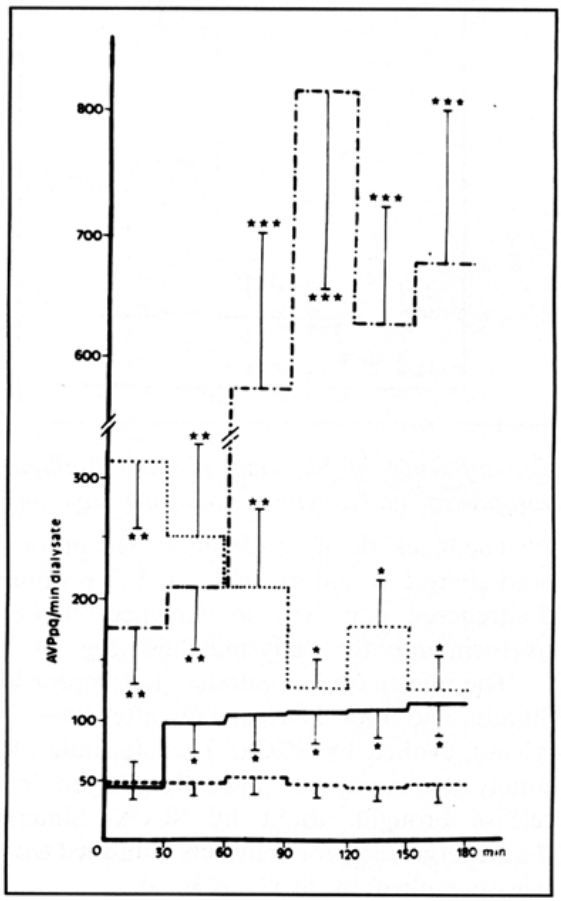

Fig. 2. Vasopressin release into the dialysate of the blood from the vicinity of cavernous sinus sella turcica [pg/ml]. ------- control; ——— after superior cervical ganglion stimulation (10 V, 20 Hz, 3 ms); —·—·—·— after the superior cervical ganglionectomy immedietly the experiment; ····· 20 day after the superior cervical ganglionectomy. * $p < 0.01$, ** $p < 0.005$, *** $p < 0.0001$ vs. control group.

caused a 4.2-fold greater release of vasopressin (*Fig. 2*) and 4.6-fold higher of oxytocin (*Fig. 3*).

Electric stimulation of preganglionic fibres of SCGx caused an increase vasopressin (*Fig. 2*) and oxytocin (*Fig. 3*) release.

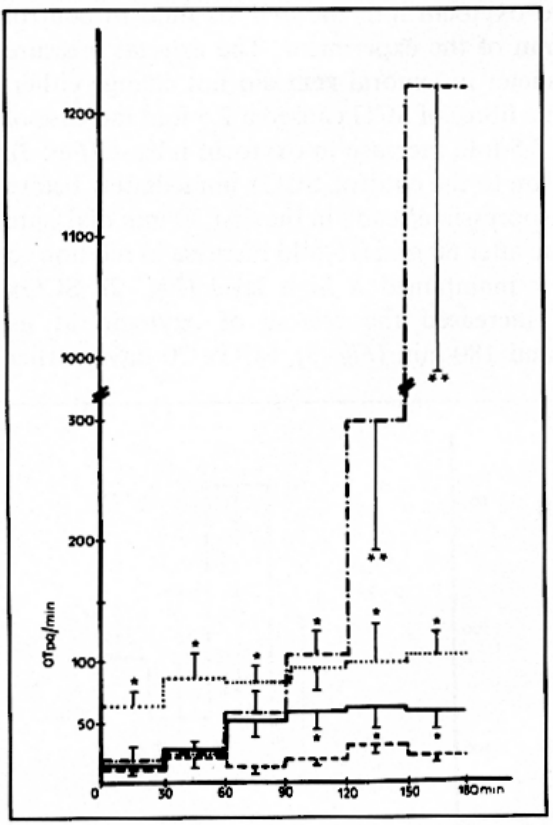

Fig. 3. Oxytocin release into the dialysate of the blood from the vicinity of cavernous sinus sells turcica [pg/ml]. ------- control; ——— after superior cervical ganglion stimulation (10 V, 20 Hz, 3 ms); —·—·—·— after the superior cervical ganglionectomy immedietly the experiment; ····· 20 day after the superior cervical ganglionectomy. * $p<0.01$, ** $p<0.005$, vs. control group.

The influence of blocking α_1- and β-adrenergic receptors on the release of vasopressin and oxytocin following superior cervical ganglionectomy.

The blockade of α_1-adrenergic receptors with an i.v. injection of prazosin or β-adrenergic receptors with an i.v. propranolol or simultaneously α_1- and β-adrenergic ones had no influence on the basic release of vasopressin and oxytocin into the dialysing fluid (*Fig. 4*).

The injection of α_1-adrenergic receptor blocker did not abolish at all after 30 min, and abolished partially after 90—120 min the increase of vasopressin release, evoked by SCGx. The blockade of β-adrenergic receptors abolished totally the initial and partially delayed in time the increase of vasopressin release brought about by SCGx. Simultaneous application of α_1- and β-adrenergic receptors blockers abolished thoroughly the increase of vasopressin release evoked by SCGx (*Fig. 5*).

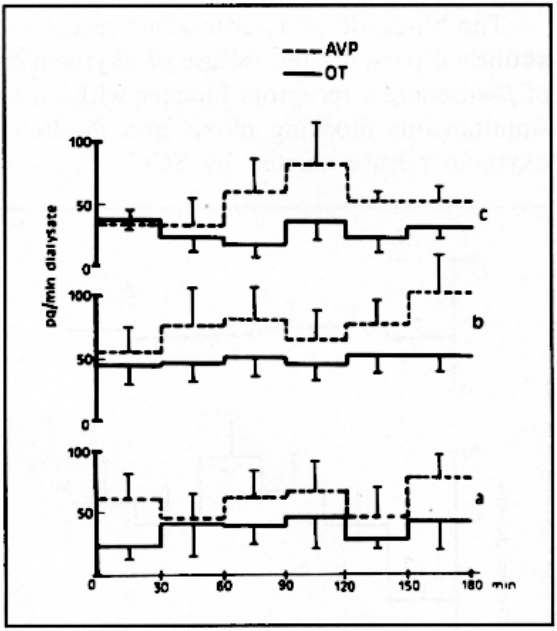

Fig. 4. Vasopressin and oxytocin release into the dialysate after intraventricular injection: a) propranol — 6.25 mg/kg; b) prazosin — 1.25 mg/kg; c) bath propranolol and prazosin. ------- vasopressin, ——— oxytocin.

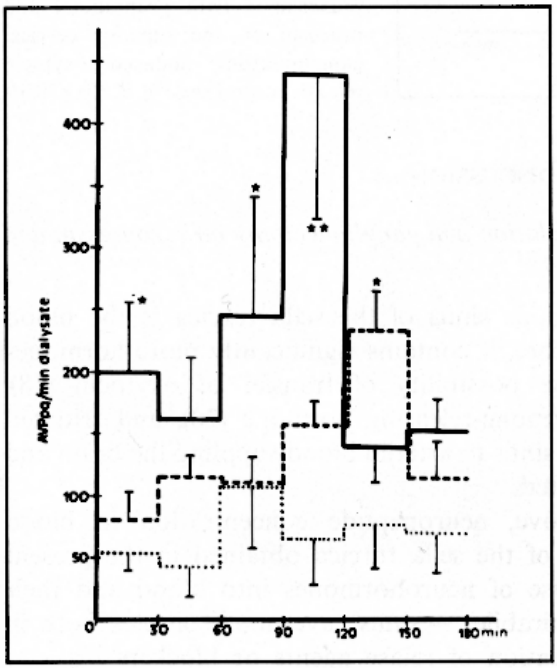

Fig. 5. Effect of ——— prazosin, - - - - - propranolol and ····· bath propranolol and prazosin on the superior cervical ganglionectomy induced vasopressin release, control see *Fig. 2.* * $p < 0.01$, ** $p < 0.005$ vs. control.

The blockade of α_1-adrenergic receptors with an i.v. injection of prazosin abolished partially the release of oxytocin caused by SCGx. However, the use of β-adrenergic receptors blocker with an injection of propranolol, as well as simultaneous blocking of α_1- and β-adrenergic receptors, entirely abolished oxytocin release elicited by SCGx (*Fig. 6*).

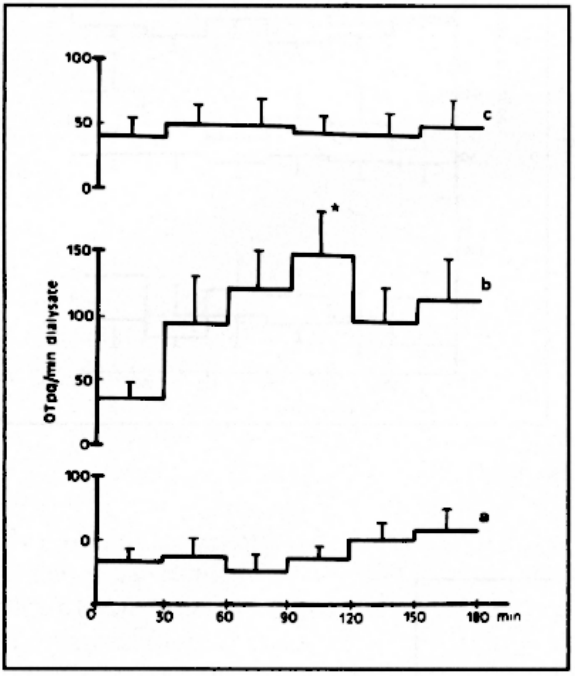

Fig. 6. Effect of: a) propranolol; b) prazosin; c) bath propranolol and prazosin on the superior cervical ganglionectomy induced oxytocin release, control see *Fig. 3.* * $p < 0.01$.

DISCUSSION

Influence of superior cervical stimulation and ganglionectomy on vasopressin and oxytocin release

Blood taken from the cavernous sinus of the sella turcica is the blood outflowing from the brain, therefore, it contains significantly more hormones than peripheral blood (17). The possibility of transfer of oxytocin (18), β-endorphin (19), luteinizing hormone-releasing hormone (20), and tritiated water (21, 22) from the cavernous sinus to arterial blood suppling the brain and hypophysis has been demonstrated.

In connection with the above, neuropeptide concentration in blood dialysates from cavernous sinus of the sella turcica obtained in the present experiment results from the relase of neurohormones into blood and their uptake in the area of the rete mirabile — sinus cavernous complex both in control animals and after application of relase agents or blockers.

The method of blood dialysis applied in the present study allows to observe the dynamics of changes in vasopressin and oxytocin release in the same animal. It enables avoiding blood sampling, which in studies on vasopressin is of extreme importance, as blooding is the strongest stimulus releasing this neurohormone into blood (23).

The histochemical fluorescence studies have indicated that after surgical removal of SCG, the large, coarse, catecholamine-containing fibers primarily associated with blood vessels in the neurointermediate lobe disappear (5). In studies performed in SCGx rats, a significant decrease in basal hypothalamic 3H-NA uptake was found (11), a 40—60% decrease in rat median eminence NA content, and decrease in vasopressin and oxytocin content in neurohypophysis (6—8). It has been also demonstrated, that in rats with removed SCG the „miniature neurohypophysis" is not formed at the proximal end of the cut pituitary stalk, while in the hypothalamus there is a degeneration of neurosecretory neurons (24).

In my present research the release of vasopressin and oxytocin was brought about by the stimulation of SCG. The frequency of electrical pulses used in my experiments was an efficient stimulus to release acetylocholine from preganglionic (25), NA and coexisting peptides from postganglionic fibres (26). The same stimulation, as regard frequency, duration, amplitude of electric pulses with the same lenght of stimulation, evoked quantitative changes of the golgi profiles and dense-core vesicles in SCG cells (27) and a decrease in amount of neurosecretory granules in the posterior pituitary lobe (28), what can indicate the lower synthesis or higher release of the transmitters. Lundberg and Hökfelt (29) revealed that the release of the transmitter and/or peptide modulators from the postganglionic endings in the autonomic nervous system, due to electric stimulation, is dependent on the characteristics of the applied stimulatory pulses. The fact of obtaining similar results, as concern the release of neurohormones resulting from the stimulation of the sympathetic efferent may be connected with release of NA and/or peptide modulators, which is dependent on the way of stimulation of this system, or the kind of receptor with which the separate chemical transmitter will bind. It is also possible that electric stimulation of preganglionic fibres of SCG causes, via peptide modulators present in SCG (30), a decrease of NA release on postganglionic endings, and in consequence, increased release of the posterior pituitary neurohormones in my experiment. In our previous work, we used short irritating pulses which release probably only the mediator (29) and do not change vasopressin and oxytocin release in the similar experimental conditions (12, 13).

My results are in accordance with results of Romeo et al. (6) who observed an increase in vasopressin and oxytocin release into the blood, and a decrease of these neurohormons in neuroitermediate lobe, 6 h after SCGx, i.e. during the first phase of nerve paralysis following the SCG ablation (30, 31).

20 days after SCGx, i.e. after a complete denervation of structures innervated by SCG (11), the content of vasopressin and oxytocin in dialysates was higher, which may result from the lack of inhibition of these neurohormones release from SCG. In physiological conditions the release of neurohormones from the posterior pituitary lobe is probably continually inhibited by pulsation from SCG; SCGx, however, neutralizes this inhibition, the consequence of which is an increased release into blood, and decreased content in the posterior pituitary demonstrated earlier (32). Attention is drawn especially to a greater release of vasopressin at the beginning of dialysis, in rats 20 days after SCGx. It may result from postdenervation hypersensitivity, and, what results from this fact, from greater sensitivity to stimuli during preparation of animals for the experiment. The effect of SCG on the release of the posterior pituitary neurohormones, may occur both directly or via the pineal gland, as the dependence between the pineal body and the release of the posterior pituitary neurohormones has been demonstrated (33, 34).

Participation of adrenergic receptors in vasopressin and oxytocin release after sympathetic denervation

There are anatomical and physiological reasons to believe that NA fibers of a central origin participate in the regulation of neurohypophysial release (35). The paraventricular and supraoptic nuclei receive a dense NA innervation, originating from the A1 area and brainstem NA areas (36, 37). Activation of the central NA input to the magnocellular nuclei augments vasopressin release. This input to AVP neurons may regulate cardiovascular function, both by an effect of vasopressin on CNS autonomic regulatory centers, or by a direct effect of the circulating vasopressin on blood pressure (38). Recently, considerable evidence has been accumulated indicating, that the subtypes of adrenoreceptor exist in various areas of the hypothalamus (39, 40, 41), and they play important roles in both pressor and depressor responses by modifying the baroreceptor reflex (42, 43) and the activity of the hypothalamus and neurohypophysial hormone release (45—50).

Intravenous infusion of both α_1- receptors blocker, prazosin, and β-receptors, propranolol, did not change significantly vasopressin and oxytocin release in control conditions. The release of vasopressin and oxytocin occurring in paralytic phase after SCGx, was partially blocked by prazosin and propranolol. At the same time β-antagonist prevented the increased release of vasopressin already in the initial phase, 30 min after SCGx, which might have been caused by manipulations connected with SCG preparation, causing an increase of vasopressin and oxytocin release into the blood (14). On the other hand, α_1-antagonist did not abolish this initial (30 min) increase in vasopressin release, whereas it partially neutralized the increase at 120 min, which may be

connected with the inhibition of NA liberation on postganglionic endings. Stimultaneous use of α_1-antagonist and β-antagonist entirely abolished the effect of increased release of vasopressin and oxytocin, evoked by SCGx.

Inhibitory or excitatory effects of NA on vasopressin and oxytocin release can depend on the adrenoceptor subtype involved in mediating mechanism. Most authors agree that the stimulating action of NA on neurones of supraoptic and paraventricular nuclei, occurs via α_1- and β-receptor, and the inhibitory action by α_2-receptor. In anesthetized dogs, the inhibition of NA release resulted from intraventricular infusion of NA, was blocked by the α_2-antagonist yohimbine, but not the α_1-antagonist, prazosin (45). In conscious rats, centrally administered NA and the α_1-agonist, phenylephrine, stimulated vasopressin release, whereas α_2-and β-agonists inhibited this release (44). In the latter study, evidence for a tonic inhibitory influence of NA on vasopressin was provided by showing elevations in plasma following the infusion of β- or α_2-antagonists. Intravenous administration of the α_2-agonist clonidine, also decreased vasopressin release in anesthetized dogs, even when its peripheral pressor effects had been abolished (45). Thus current results of *in vivo* studies would suggest that central α_2- and β-adrenoceptors mediate the inhibitory effect of NA on vasopressin release, whereas the α_1- subtype mediates excitation. The inhibition of AVP release in cultured MBH explants *in vitro* by NA and its prevention by nonspecific α-antagonists provides evidence that these receptors are localized within the ventral hypothalamus, and perhaps on the supraoptic nuclei themselves (38). Romeo *et al.* (6) demonstrated that both increased vasopressin release occuring 6 h after SCGx and decreased vasopressin release taking place 16 h after SCGx involved α_1-adrenergic receptors. Recent studies revealed that stimulating or inhibiting influence of receptors may depend on the amount of released mediator and possibly on the functional state of neurosecretory neurons (51), and also on modulators colocalized with NA (52). Systemic administration of the α_2-adrenoreceptor antagonist, idazoksan supressed oxytocin cell bursting activity, while having no consistent action on basal neuronal activity in the rat. Clonidine (25 μg/kg, i.v.) caused an immediate increase in the frequency and amplitude of oxytocin cell bursting coincident with a fall in basal activity. A high dose of clonidine (51 μg/kg, i.v.), inhibited both bursting and basal activity (52). Kahana et al. (53) have reported that the NA-induced inhibition of AVP release α_2-receptors depended fulfilling autoinhibitory roles involve presynaptic α_2- receptors by neuropeptide-Y, which is co-stored with NA.

Summing-up, SCG in physiological conditions may fulfil an inhibitory role in the release of neurohormones from neurohypophysis into the blood. Change of pulsation from SCG increases the release of vasopressin and oxytocin from the posterior pituitary lobe. It occurs partially in the presence of α_1-, and

partially, β-adrenergic receptors. It has been demonstrated that functional dependence between the posterior pituitary lobe and the pineal gland occurs via β-receptor (47). Attention should be drawn to the fact that intravenous infusion of blockers may arouse peripheral and partially central effects. Nevertheless, the possible peripheral effects of prazosin and/or propranolol administered intravenously and the function of vasopressinergic and oxytocinergic neurones thereby altered (e.g., by modified afferentation of volume- and/or baroreceptor origin) cannot be excluded.

Acknowledgements: I thank Professor W. Z. Traczyk for his helpful comments on the manuscript. I would like to express may gratitude to Agnieszka Żebrowska-Badala M. Sc., for her technical assistance during the experiments, Monika Orłowska-Majdak, Ph. D., for supplying the anti-vasopressin and anti-oxytocin antiserum and Jadwiga Kaczorowska-Skóra, M. Sc., for performing hormone radioimmunoassay.

The study was supported by a grant for Medical University of Lodz.

REFERENCES

1. Sawchenko PE, Swanson LW. The organization of noradrenergic pathways from the brainstem to the paraventricular and supraoptic nuclei in the rat. *Brain Res Rev* 1982; 4: 275—325.
2. Cardinali DP, Vacas MI, Gejman PV. The sympathetic superior cervical ganglia as peripheral neuroendocrine centers. *J Neural Transm* 1981; 52: 1—21.
3. Cardinali DP, Romeo HE, Vacas MI. Neuroendocrine projections of superior cervical ganglia. *Adv Pineal Res* 1987; 2: 35—49.
4. Saavedra JM. Central and peripheral catecholamine innervated the rat intermediate and posterior pituitary lobes. *Neuroendocrinology* 1985; 40: 281—284.
5. Alper RH, Demarest KT, Moore LE. Effects of surgical sympathectomy on catecholamine concentrations in the posterior pituitary of the rat. *Experientia* 1980; 36: 134—135.
6. Romeo HE, Spinedi E, Esquifino AI, Estivariz F, Cardinali DP. Anterograde nerve degeneration after superior cervical ganglionectomy coexists with a decrease of arginine vasopressin release in rats. *Neuroendocrinology* 1991; 54: 346—352.
7. Lipińska S, Rubacha G, Traczyk WZ. The effects of cervical sympathectomy on vasopressin and oxytocin content in rats posterior pituitary lobe. *Ann Acad Med Lodz* 1980; XXI suppl 21: 93—99.
8. Fendler K, Endroczi E, Lissak K. The effect of cervical sympathectomy on posterior pituitary oxytocic activity in rats under chronic stress. *Acta Physiol Hung* 1965; 27: 275—278.
9. Cardinali DP, Romeo HE, Boado RJ, Deza S. Early inhibition and changes in diurnal rhytmicity of the pituitary-thyroid axis after superior cervical ganglionectomy of rats. *J Auton Nerv Syst* 1986; 16: 13—21.
10. Cardinali DP; Romeo HE, Vacas MI. Neuroendocrine projections of superior cervical ganglia. *Adv Pineal Res* 1987; 2: 35—49.
11. Cardinali DP, Vacas MI, Fortis AL, Stefano FJE. Superior cervical ganglionectomy depresses norepinephrine uptake, increases the density of alpha-adrenoceptor site, and induces supersensitivity to adrenergic drugs in rat medial basal hypothalamus. *Neuroendocrinology* 1981; 33: 199—206.
12. Lipińska S, Orłowska-Majdak M, Traczyk WZ. Vasopressin release from posterior pituitary lobe incubated in situ after preganglionic stimulation of the rat superior cervical ganglion. *J Physiol Pharmacol* 1992; 43: 367—372.

13. Lipińska S, Orłowska-Majdak M, Traczyk WZ. Oxytocin release from the posterior pituitary lobe after preganglionic stimulation of the superior cervical ganglion in rats. Endokrynol Pol — Polish J Endocrinol 1995; 46: 311—316.
14. Lipińska S, Orłowska-Majdak M, Traczyk WZ. Increase in oxytocin and vasopressin concentration in the blood outflowing from sella turcica region after superior cervical stimulation in rat. *J Physiol Pharmacol* 1996; 47,2: 281—288.
15. Gorąca A, Traczyk WZ. Increase in cardiodepressant factor release from the posterior pituitary lobe after angiotensin II infusion into the internal carotid artery. *J Physiol Pharmacol* 1997; 48: 225—237.
16. Ciosek J, Orłowska-Majdak M. Thyrotropin-releasing hormone (TRH) inhibits the release of vasopressin but that of oxytocin from the hypothalamo-neurohypophysial system in haemorrhaged rats. *Endocrine Regul* 1995; 29: 47—55.
17. Gorąca A. Increase in vasopressin concentration and cardiodepressant activity in the blood dialysates after NMDA and hypertonic saline administration. *J Physiol Pharmacol* 1998: 49: 561—575.
18. Grzegorzewski W, Skipor J, Wasowska B, Krzymowski T. Courent current transfer of oxytocin from the venous blood of the perihypophyseal cavernous sinus to the arterial blood of carotid rete suppling the hypophysis and brain depends on the phase of the estrous cycle in pigs. *Biol Reprod* 1995; 52: 139—144.
19. Skipor J, Grzegorzewski W, Wasowska B, Krzymowski T. Counter current transfer of beta-endorphin in the perihypophyseal cavernous sinus carotid rete vascular complex of sheep. *Exp Clin Endocrinol Diabetes* 1997, 105: 308—313.
20. Grzegorzewski WJ, Skipor J, Wasowska B, Krzymowski T. Counter current transfer of ^{125}I-LHRH in the prihypophyseal cavernous sinus-carotid rete vascular complex, demonstrated on isolated pig heads perfused with autologous blood. *Domest Anim Endocrinol* 1997, 14: 149—160.
21. Einer-Jensen N. Local transfer of tritiated water from the nasal cavity to brain arterial blood in rats. *J Physiol Pharmacol* 1996; 47 suppl 1: 73.
22. Einer-Jensen N. High radioactivity in brain arterial blood than in general arterial blood after nasal application of tritiated water in rats. XXXIII International Congress of Physiologycal Sciences 1997 St.Petersburg, Abstracts P096.04.
23. Kasting NW. Stimultaneous and independent release of vasopressin and oxytocin in the rat. *Can J Physiol* 1988; 66: 22—26.
24. Fendler K, Vermes I, Stark A, Lissak K, Effect of cervical sympathectomy on the development of "miniature neurohypophysis" and on the neurosecretory nuclei of the hypothalamus after transection of the pituitary stalk. *Neuroendocrinology* 1970; 6: 194—196.
25. McLachlan EM. An analysis of the release of acetylocholine from preganglionic nerve terminals. *J Physiol* (London) 1975; 245: 447—466.
26. Haefely W, Hürliman A, Thoenen H. Relation between the rate of stimulation and quantity of noradrenaline liberated from sympathetic nerve endings in isolated perfused spleen of the cat. *J Physiol* (London) 1965; 181: 48—54.
27. Karasek M, Lipińska S, Pawlikowski M. Quantitative changes of the Golgi profiles and dense-core vesicles in the rat superior cervical ganglion cells after preganglionc nerve stimulation. *Acta Med Pol* 1980; 21: 353—354.
28. Karasek M, Traczyk WZ, Orłowska-Majdak M, Rubacha G. Quantitative changes of the neurosecretory granules in the rat neurohypophysis after preganglionic stimulation of the superior cervical ganglion. *Acta Med Pol* 1980; 21: 351—352.
29. Lunberg JM, Hökfelt T. Coexistence of peptides and clasical neurotransmitters. *Trends Neurosci* 1983; 6: 325—333.
30. Ariano MA, Kenny SL. Peptide coincidence in rat superior cervical ganglion. *Brain Res* 1985; 340: 181—185.

31. Emmelin N, Trendelenburg U. Degeneration activity after parasympathetic or sympathetic denervation. *Rev Physiol Biochem Exp Pharmacol* 1972; 66: 148—204.
32. Cardinali DP, Romeo HE. Neuroendocrine interrelationships in the cervical region. *Newy Physiol Sci* 1990; 5: 100—104.
33. Juszczak M, Guzek JW, Lewy A.The influence of melatonin on the content of vasopressin and oxytocin in the hypopthalamus and neurohypophysis in euhydrated and dehydrated male rats. *J Pineal Res* 1986; 3: 199—211.
34. Juszczak M, Guzek JW.The hypothalamic and neurohypophysial vasopressin and oxytocin in melatonin-treated pinealectomized male rats. *J Pineal Res* 1988; 5: 545—552.
35. Khanna S, Dibbald JR, Day TA. Alpha 2-adrenoceptor modulation of A 1 noradrenergic neuron input to supraoptic vasopressin cells. *Brain Res* 1993; 613: 164—167.
36. Trevor A, Day, Doug W, Buller S, Buller KM. Regulation of neurosecretory cell activity by A1 noradrenergic neurons. *In* Neurohypophysis: recent progress of vasopressin and oxytocin research. Publ. by: Elsevier Science B.V. Amsterdam 1995.
37. Gieroba ZJ, Blessing WW. Vasopressin secretion after stimulation of abdominal vagus in rabbit: role of A1 norepinephrine neurons. *Am J Physiol* 1994; 266: R1885—R1890.
38. Armstrong WE, Gallagher MJ, Sladek CD. Noradrenergic stimulation of supraoptic neuronal activity and vasopressin in vivo. *Brain Res* 1986; 365: 192—197.
39. Miach PJ, Dausse JP, Meyer P. Direct biochemical demonstration of two types of α-adrenoceptor in the brain. *Nature* 1978; 274: 492—501.
40. Young III WS, Kuhar MJ. Noradrenergic α_1 and α_2 receptor: light microscopic autoradiografic localization. *Proc Nat Acad Sci USA* 1980; 77: 1696—1703.
41. Tsushima H, Fujimoto S, Matsuda T. Effects of beta 1- and beta 2-adrenoceptor agonists applied into the hypothalamic paraventricular nuclei of spontaneously hypertensive rats on urine production. *Jpn J Pharmacol* 1994; 64: 201—207.
42. Kubo T,Tisu Y. Pharmacological characterization of the α-adrenoceptors responsible for a decrease of blood pressure in the nucleus tractus solitari of the rat. *Naunyn-Schmiederbergs Arch Pharmacol* 1981; 317: 120—126.
43. Doxey JC, Frank LW, Herson AS. Studies on the pre- and postjunctional activities of α-adrenoceptor agonists and their cardiovascular effects in the anesthetized rat. *J Auton Pharmacol* 1981; 1: 157—162..
44. Brooks DP, Share L, Crofton JT. Central adrenergic control of vasopressin release. *Neuroendocrinology* 1985; 42: 416—420.
45. Kimura T, Sahoji M, Itake K, Ota K, Matusi K, Yoshinaga K. The role of central α- i β-adrenoceptors in the regulation of vasopressin an and the cardiovascular system. *Endocrinology* 1984; 114: 1426—1432.
46. Guzek JW, Janus J. The hypothalamic and neurohypophysial vasopressor and oxytocic activities as influenced by beta-adrenergic blockade during long-term dehydration in the white male rats. *Endokrinologie* 1980, 75: 57—66.
47. Guzek JW, Juszczak M. The effects of beta-adrenergic blokade on the hypothalamic and neurohypophysial vasopressin and oxytocin content in pinealectomized male rats. *Exp Clin Endocrinol* 1987; 89: 97—104.
48. Boer GJ, Fenstra MG, Botterblom MJ, Korse-V; Te-Riele-P. Early postnatal appearance of enhanced noradrenaline content in the brain of vasopressin-deficient Bratleboro; rat; normal adrenoceptor densities and abberrant influences of vasopressin treatment. *Int J Dev Neurtosci* 1995; 13: 63—74.
49. Tsushima H, Fujimoto S. Alpha-adrenoceptor subtyp in the hypothalamic paraventricular nucleus involved in the regulation of urine production: comparison between Wistar Kyoto and spontaneously hypertensive rats. *Jpn J Pharmacol* 1997; 74: 95—98.

50. Shioda S, Yada T, Muroya S, Takigawa M; Nakai Y. Noradrenaline activates vasopressin neurons via alpha 1-receptor-mediated Ca^{2+} signaling pathway. *Neurosci Lett* 1997; 226: 210—212.
51. Reid IA, Nolan PP, Wolf JA, Keil LC. Suppresion of vasopressin secretion by clonidine: Effect of α-adrenoceptor antagonists. *Endocrinology* 1979; 104: 1403—1406.
52. Bailey A, Clarke G, Wakerley J. The role of alpha-2 adrenoceptors in the regulation of oxytocin neurones in the suckled rat. *Brain Res Bull* 1997; 44: 193—197.
53. Khana S, Sibbad JR, Day T. Neuropeptide Y modulation of A1 noradrenergic neuron input to supraoptic vasopressin cells. *Neurosci Lett* 1993; 161: 60—64.

Received: September 1999
Accepted: November 24, 1999

Author's adress: Dr Stanisława Lipińska, Department of Physiology, Institute of Physiology and Biochemistry, Medical University of Lodz, Lindleya 3, 90-131 Lodz, Poland, tel./fax (48-42) 678-26-61.