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Corticosteroids Influence the Action Potential Firing Pattern of Hippocampal Subfield CA3 Pyramidal Cells

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Abstract

Corticosteroids regulate gene expression through the activation of mineralocorticoid and glucocorticoid receptors. The hippocampus contains the highest density of mineralocorticoid and glucocorticoid receptors in the central nervous system. The modulation of neuron excitability by corticosteroids in hippocampal subfield CA1 is well documented. However, it is not known whether corticosteroids produce different effects across the various hippocampal subfields. Therefore, we used intracellular recording techniques to examine the actions of chronic corticosteroid treatment (2 weeks) on the electrophysiological properties of rat hippocampal subfield CA3 pyramidal cells. The treatment groups used in this investigation were: adrenalectomy (ADX), selective mineralocorticoid receptor activation with aldosterone (ALD), mineralocorticoid and glucocorticoid receptor activation with high levels of corticosterone (HCT), and SHAM. Corticosteroid treatment altered the percentage of nonburst and burst firing neurons. The percentages of nonbursting cells were 74 and 62% in tissue from ADX and HCT animals compared to 42 and 41% in ALD and SHAM animals, respectively. The corticosteroid-induced effect on the ratio of nonbursting to bursting cells does not appear to be secondary to changes in the cell's membrane input resistance, resting potential, time constant, action potential, slow-or fast-afterhyperpolarizing potential properties. Based on these results we conclude that corticosteroids are important for maintaining the ratio of nonburst and burst firing pyramidal neurons in subfield CA3. These novel results are distinct from those previously reported for subfield CA1, suggesting that corticosteroids have different effects across hippocampal subfields.

Keywords

Adrenal steroids; Hippocampus; Adrenal steroid receptors; Electrophysiology

Introduction

Corticosteroids are steroid hormones that maintain homeostasis by influencing energy production and electrolyte balance [1–3]. Corticosteroids regulate gene expression through two receptor subtypes: mineralocorticoid receptor (MR, or type I) and glucocorticoid receptor (GR, or type II) [4], which have different affinities for corticosterone (MR > GR) [5–7].

The hippocampus contains the highest concentration of corticosteroid receptors in the central nervous system [5, 8–13]. Corticosteroids have a profound influence on cells in the hippocampus [14, 15]. The effects of MR and GR activation on pyramidal cell excitability and ionic currents are well documented for hippocampal subfield CA1 [16–19]. However, the effects of corticosteroids on neuron electrophysiological properties in subfield CA3 are not known.

Corticosteroids may have different effects in subfield CA3 based on the observation that the MR/GR ratio is 1:1 in subfield CA3 as compared to 6.5:1 in CA1 as determined by a receptor binding investigation [5]. More significantly, it is important to determine the effects of corticosteroids in subfield CA3 by virtue of the distinct and unique roles subfield CA1 and CA3 have in hippocampal information processing. For example, the pyramidal cells in subfield CA1 and CA3 have different passive and active electrical membrane properties [20–23]. The pyramidal cells in subfield CA1 and CA3 also display different proportions of burst and nonburst action potential firing patterns [24, 25]. Generally, in adult rats, subfield CA3 displays a higher proportion of burst firing neurons compared to CA1.

We used intracellular recording techniques to examine the effects of chronic corticosteroid treatment on the electrophysiological properties of pyramidal cells in hippocampal subfield CA3. Our hypothesis is that corticosteroids will produce a different modulatory action in subfield CA3 neurons as compared to those previously reported for subfield CA1. These results will contribute to a basic understanding of how corticosteroids alter cell excitability and will help to elucidate the role of corticosteroids receptors in information processing in the hippocampus.

Materials and Methods

Animals

Four different treatment groups were used for the experiments in this investigation (table 1). The adrenalectomy was performed as described previously [19, 26, 27]. Male Sprague-Dawley rats (Harlan), 75–100 g, were used for all treatment groups. Bilateral adrenalectomies were performed on all treatment groups, except the SHAM group, to remove circulating corticosteroids. The animal was anesthetized with ether, a small incision was made into the abdominal cavity, just below the rib cage, and the adrenal glands carefully removed. The muscle wall was then sutured and the skin closed using wound clips. The ADX group received no further treatment. The ALD group had an osmotic minipump containing aldosterone (Alzet model 2002 from Alza Cooperation, Palo Alto, Calif., USA) implanted subcutaneously at the time of adrenalectomy, to selectively activate MR. The minipump delivered 10 µg/h aldosterone (Steraloids, Inc., Wilton, N.H., USA) dissolved in propylene glycol. MR and GR were activated in another group of animals (HCT) by subcutaneously implanting 200–300 mg corticosterone pellets, 2- to 3-week release (Innovative Research, Sarasota, Fla., USA), in the back of the neck at the time of adrenalectomy. The SHAM group of animals was produced by visualizing the adrenal glands but leaving them intact. After surgery the animals were maintained on a standard 12-hour light/dark cycle and rat chow, ad libitum. SHAM animals were given standard drinking water while the ADX, ALD, and HCT animals were given 0.9% NaCl drinking water ad libitum. At the end of 13–15 days, the animals were sacrificed in the morning and hippocampal slices immediately prepared for electrophysiological recording. At the time of sacrifice, trunk blood was collected to determine the plasma corticosterone levels by radioimmunoassay [28].

Hippocampal Slice Preparation

Hippocampal slices were prepared for electrophysiological recording as previously described [29]. The rats were sacrificed by decapitation and the brain was rapidly removed and placed in ice-cold artificial cerebrospinal fluid (ACSF) containing (mM): NaCl 125, KCl 3, NaH₂PO₄ 1.25, MgSO₄ 2, CaCl₂ 2.5, dextrose 10, and NaHCO₃ 28. The ACSF was also supplemented with steroids, as outlined in table 1, to maintain the treatment paradigm. We have previously reported that steroids must be present in the ACSF to preserve the corticosteroid-induced effects on neuron cell properties [19]. The hippocampus was dissected free and the dorsal portion cut into 500- to 550- μ m sections on a vibratome. The hippocampal slices were then placed in a holding vial containing ACSF bubbled with 95% O₂-5% CO₂ at room temperature. The slices remained in the holding vial for at least 1 h after dissection before being transferred to the recording chamber. In the recording chamber, the slice was stabilized between two nylon nets and continuously perfused with ACSF bubbled with 95% O₂-5% CO₂ at a rate of 2–3 ml/min, at 31–32 °C.

Intracellular Recording

Intracellular recordings were made as previously described [29]. Electrodes were pulled from borosilicate capillary tubing on a Brown and Flaming electrode puller (Sutter Instruments, Novato, Calif.) to a resistance of 30–35 M Ω (2 M KCl). Pyramidal cells were impaled with brief ejections of positive current through the electrode. The impaled cells were sealed by applying 1 nA hyperpolarizing current which was slowly reduced to zero where the cell's membrane potential stabilized (10–20 min after initially impaling the cell). Data for cell characteristics were obtained only after the cell's membrane potential stabilized with no holding current. Only cells with an input resistance greater than 25 M Ω that were not spontaneously firing action potentials were used for analysis. Signals were collected and amplified using an Axoclamp 2A and Cyberamp 320 amplifier (Axon Instruments, Foster City, Calif., USA) and recorded on a Gould Series 3200 chart recorder (Gould Electronics, Valley View, Ohio, USA). Data were collected on line with pCLAMP software (Axon Instruments).

Statistical Analysis

Statistical comparisons were performed using analysis of variance (ANOVA). The Student-Newman-Keuls method was used for post-hoc tests. A χ^2 test was used to determine whether the percentage of bursting and nonbursting cells was different with corticosterone treatment. All values are reported as mean $\pm$ SEM. A $p < 0.05$ was considered significant.

Results

Corticosterone Plasma Levels

SHAM corticosterone plasma levels ranged from 0 to 4.13 μ g/dl (1.23 ± 0.24 μ g/dl, $n = 22$). ADX corticosterone plasma levels ranged from 0 to 0.5 μ g/dl (0.21 ± 0.05 μ g/dl, $n = 20$). ALD corticosterone plasma levels ranged from 0 to 0.6 μ g/dl (0.12 ± 0.05 μ g/dl, $n = 18$). The lower and upper limits of the corticosterone radioimmune assay were 0.05 and 50 μ g/dl, respectively. Adrenalectomies that produced corticosterone concentrations ≤ 0.6 μ g/dl were considered successful. Two SHAM, 12 ADX, and 13 ALD animals had corticosterone levels less than 0.05 μ g/dl. The concentration of aldosterone used in our experiments was based on an investigation by Kuroda et al. [30]. The ALD treatment decreased MR binding by 61% ($n = 5$ animals) in the cytoplasm (data not shown) as determined using a homogenate binding assay. HCT corticosterone plasma levels ranged from 25 to > 50 μ g/dl (39.96 ± 2.90 μ g/dl, $n = 11$).

Burst and Nonburst Firing Cells

The analysis of cell characteristics was as described previously [19]. Two different firing modes have been described for pyramidal neurons in the hippocampus [24, 25, 31–33]. One type of firing mode is a regular spiking pattern of independent action potentials in response to a long depolarizing pulse (nonbursting cells) while the other mode is a cluster of spikes which reside on a slow depolarizing potential (bursting cells). In the present investigation, nonburst firing cells were identified by action potentials which fired at a common membrane potential, with equal duration and no underlying depolarization (fig. 1A). Bursting cells were identified by a close cluster of action potentials which resided on a depolarizing hump at the beginning of the stimulation pulse (fig. 1B). The action potential threshold and duration of a bursting cell were also variable. Action potentials occurring in the middle of the burst fired before the preceding spike completely repolarized. Therefore, these action potentials fired at a higher threshold and were broader compared to the initial spikes (fig. 1C). A χ^2 analysis indicated that the percentage of burst and nonbursting cell types was dependent on the type of corticosteroid treatment (table 2). The largest differences were observed with ADX animals where the percentage of nonbursting cells was 74% compared to 42 and 41% in ALD and SHAM animals. A greater percentage of nonbursting cells were also observed in slices from HCT animals (62%).

Burst and nonburst firing is influenced by Na^+ , K^+ , and Ca^{2+} ion currents [32, 33, 35–37]. Therefore, we hypothesized that corticosteroids may also alter pyramidal cell passive and active membrane characteristics. Data on several passive and active membrane properties were first analyzed using a two-way ANOVA with treatment as one variable and cell type as the other variable. If there were no significant effects between nonburst and bursting cell type, the data were then analyzed using one-way ANOVA, collapsing across cell type and grouping according to treatment only.

The membrane potential was read directly from the amplifier display. Corrections for the input offset were done after the electrode was withdrawn from the cell. The membrane input resistance and membrane time constant were calculated from current-voltage plots. The current-voltage plot data were generated by injecting 300-ms pulses of -900 to 0 pA in 100 -pA increments into the cell while recording the cell's membrane potential. The membrane input resistance was calculated from the slope of the linear portion of the current-voltage plots. The membrane time constant corresponded to the length of time required for the membrane potential to reach 63% of its final value during a 300-ms pulse of -100 pA. There were no differences in resting membrane potential, input resistance, or membrane time constant between either cell type of corticosteroid treatment (table 3).

Action Potential and Fast Afterhyperpolarizing Potential Properties

Table 4 summarizes the effects of corticosteroids on action potential and fast after hyperpolarizing potential (fAHP) properties. Action potentials were generated with short 2- to 4-ms depolarizing pulses. The action potential threshold was the membrane potential value just before the action potential spike began to rise. The action potential threshold was used as the baseline value to calculate its height and baseline duration. The action potential height was measured from baseline to the peak of the spike. The action potential half-width was the width of the spike at 50% of its peak amplitude. The action potential baseline duration was the spike width along its baseline. fAHPs were generated with 20-ms pulses of enough current (300–600 pA) to generate a single action potential. The fAHP amplitude was measured from threshold to the peak hyperpolarizing amplitude which occurred 1–4 ms after the end of the spike. The fAHP $t_{1/2}$ corresponds to the amount of time for the fAHP to decrease from its peak amplitude to one-half of its value.

Based on a two-way ANOVA examination, neither corticosteroid treatment nor cell type had an effect on the action potential threshold. The action potential peak amplitude was smaller in bursting cells (80.3 ± 0.7 mV, $n = 52$) compared to nonbursting cells (82.7 ± 0.6 mV, $n = 69$) ($F = 6.252$; d.f. = 1, 113; $p = 0.014$). However, corticosteroid treatment had no effect on the action potential peak amplitude ($F = 2.021$; d.f. = 3, 113; $p = 0.115$). Corticosteroid treatment did alter the action potential duration. The action potential half- and baseline widths were wider in cells from ADX animals compared to cells from ALD and HCT animals (fig. 2). The action potential half-width was also wider in cells from SHAM animals compared to ALD.

Slow Afterhyperpolarizing Potentials and Accommodation

The effects of corticosteroids on slow afterhyperpolarizing potential (sAHP) and accommodation properties are summarized in table 5. sAHPs were generated by injecting 300–500 ms pulses of 800–1,200 pA to elicit a train of sodium action potentials. A train of sodium action potentials usually generates two types of afterhyperpolarizing potentials, a medium-afterhyperpolarizing potential followed by an sAHP [38]. Therefore, the sAHP amplitude was measured after the medium-afterhyperpolarizing potential ended (approximately 100–250 ms after the current pulse terminated). The sAHP $t_{1/2}$ corresponds to the amount of time for the sAHP to decrease from its peak amplitude to one-half of its baseline value. Spike accommodation corresponds to the number of action potentials that occurred during a 300-ms depolarizing pulse.

Two-way ANOVA analysis of the data indicated that the sAHP amplitude was smaller in nonbursting cells (10.8 ± 0.5 mV, $n = 65$) compared to bursting cells (12.4 ± 0.5 mV, $n = 38$) ($F = 5.822$; d.f. = 1, 111; $p = 0.017$). Consistent with the larger sAHP in bursting cells, accommodation was also greater in bursting cells (4.5 ± 0.47 spikes, $n = 53$) compared to nonbursting cells (5.7 ± 0.3 , $n = 64$) ($F = 5.743$; d.f. = 1, 110; $p = 0.018$). Corticosteroid treatment had no effect on the sAHP amplitude ($F = 2.096$, d.f. = 3, 111; $p = 0.105$) or accommodation properties ($F = 0.04$; d.f. = 3, 110; $p = 0.989$).

Discussion

We examined the effects of corticosteroids on pyramidal cell electrical properties in subfield CA3. The primary finding was that the percentage of nonbursting and bursting cell types was dependent upon corticosterone treatment. The shift in the nonbursting to bursting cell type ratio may be secondary to changes in the cell's resting and active membrane properties. Therefore, we analyzed the cell characteristics according to treatment and cell type. There were several cell characteristics that were different between nonbursting and bursting cell types. Nonbursting cells had a larger action potential peak amplitude, less accommodation, and a smaller sAHP amplitude compared to bursting cells. However, corticosteroid treatment had no effect on these cell characteristics. Corticosteroids also had no effect on the passive membrane properties (membrane potential, input resistance, and time constant), fAHP amplitude and duration. The action potential duration was longer in cells from ADX animals compared to ALD and HCT. The action potential duration was also longer in cells from SHAM animals compared to ALD.

Percentage of Nonbursting and Bursting Cells

The pyramidal cells in subfield CA3 are divided into bursting and nonbursting cell types, depending on their firing pattern. A single cell may produce both burst and nonburst firing patterns depending on the membrane potential and extracellular K^+ concentration [31]. Bursting cells produce a burst of 3–5 action potentials on top of a slow depolarizing envelope [24, 25, 31–33]. The percentage of nonbursting cells we observed in subfield CA3

in SHAM and ALD animals (41–42%) is similar to the values reported for naive animals (40–41%) [24, 25]. Both ADX and HCT treatment increased the percentage of nonbursting cells to 74 and 62%, respectively; however, further experiments are required to address the mechanism(s) by which ADX and HCT influence the cell firing pattern.

Corticosteroids have been reported to alter pyramidal cell characteristics in subfield CA1 [16–19]. Initially, we hypothesized that the ADX-associated increase in non-bursting cells in subfield CA3 may be due to changes in the cell's membrane electrical properties. Nonbursting and burst firing cells do have different action potential peak amplitudes, accommodation, and sAHP amplitudes; however, corticosteroid treatment did not alter these properties. Corticosteroids also did not alter the resting membrane potential, input resistance, or time constant in subfield CA3 pyramidal neurons. Therefore, the corticosteroid-associated shift in the ratio of burst/nonburst firing cells in subfield CA3 does not appear to be secondary to changes in the passive membrane and action potential properties.

A possible explanation for the increased number of nonbursting cells is that corticosteroids modulate the ionic current that influences the burst firing mode. Burst firing is generally attributed to a prolonged afterdepolarization (ADP or DAP) [33, 37] via slow Ca^{2+} [32, 33] and/or Na^+ [34, 36, 37, 39] currents. Under our present action-potential-generating protocol, we were not able to observe ADPs. The effects of corticosteroids on isolated Ca^{2+} and Na^+ currents in subfield CA3 are not known. However, corticosteroids have been shown to influence Ca^{2+} currents in subfield CA1 [17, 40, 41] and Ca^{2+} homeostasis [42].

It is possible that the ADX-associated increase in non-bursting cells in subfield CA3 is due to events occurring in the dentate gyrus. Adrenalectomy has been reported to induce granule cell degeneration in the dentate gyrus 1–3 weeks after adrenalectomy [43, 44]. The most severe cell loss occurs after 4 or more months from adrenalectomy [44–49]. The loss of granule cell and subfield CA3 pyramidal cell synapses induced by adrenalectomy may account for the large shift in the percentage of nonbursting cells. However, the granule cell loss appears to selectively attenuate only the currents associated with burst/nonburst firing since we did not observe any pronounced changes in the passive or active membrane characteristics.

Comparisons to Subfield CA1

The effects of corticosteroids on burst/nonburst firing in subfield CA1 are not known. However, several important comparisons on the effects of corticosteroids can still be made between subfields CA1 and CA3. Corticosteroids had no effect on the cell's membrane resting potential, input resistance, or time constant in subfield CA3. Similar results were reported for subfield CA1 neurons from ADX and SHAM animals in earlier investigations [16–19]. In contrast, the membrane input resistance and time constant in subfield CA1 pyramidal cells are altered by corticosteroids [19]. The changes in CA1 cells may be due to alterations in I_Q [19, 50], which is less prominent in CA3 cells [23]. The membrane input resistance and time constant determine the decay of synaptic potentials in the dendrites and soma, thereby influencing the integration of postsynaptic potentials [51]. Therefore, corticosteroids may have different effects on the integration of postsynaptic potentials in subfield CA1 and CA3.

Corticosteroids play a role in the shaping of action potentials in both subfield CA1 and CA3 pyramidal cells. However, the effects of corticosteroid on the action potential duration is different between the two subfields. In subfield CA3, the action potential half- and baseline width is decreased in cells from ALD and HCT animals compared to cells from SHAM and ADX animals. Corticosteroids have the opposite effects in subfield CA1. Chronic low

(basal) levels of corticosterone increased the action potential height and duration and decreased the fAHP amplitude [19] when compared to cells from ADX animals.

The sAHP and accommodation characteristics in cells from subfield CA1 were the first electrophysiological membrane characteristics identified that were altered by corticosteroids [16–18]. Both of these properties rely on a Ca^{2+} -dependent K^{+} current [38, 52]. Unlike the cells in subfield CA1, corticosteroids did not alter the sAHP or accommodation in subfield CA3 neurons. Nevertheless, as discussed below, there is an interesting parallel between corticosteroid receptors activation, spike accommodation and sAHP amplitude in subfield CA1, and the percentage of nonbursting cells in CA3.

Role of Corticosteroid Receptors

MR and GR are postulated to have unique and often opposite physiological roles [3, 4, 6, 14]. The different electrophysiological properties we observed in hippocampal neurons from ADX, ALD, and HCT animals also supports this hypothesis.

The different percentage of nonbursting cells observed in the present investigation can be understood in terms of MR and GR occupation. The higher percentage of non-bursting neurons observed in ADX compared to SHAM and ALD animals leads us to conclude that MR occupation provides an important basal influence on neuron action potential firing patterns. When corticosteroid levels are chronically elevated by the coactivation of MR and GR, the percentage of nonbursting neurons is increased, therefore altering the influence MR activation has on the neuron's action potential firing pattern. This pattern of MR and GR function is similar to the relationship between corticosteroid receptor function and the sAHP, initially demonstrated by Joëls et al. [16, 18]. In subfield CA1, adrenalectomy, or the coactivation of MR and GR, increased spike accommodation and the sAHP amplitude. Short-term and chronic MR activation decreased spike accommodation and sAHP amplitude [17–19].

Evaluating the possible roles of MR and GR on action potential properties is not straightforward. There are at least two factors influencing the action potential properties observed in the present investigation. First is the direct effects of corticosteroids on the ion channels underlying the action potential. Second, bursting and non-bursting cells may have different action potential properties. Therefore the corticosteroid-induced effects on the action potential properties observed in the present investigation may reflect a change in the ratio of bursting and nonbursting cells.

In spite of these complicating factors, certain preliminary interpretations can be made based on our results. First, the wider action potential width in neurons from ADX compared to ALD and HCT animals leads us to conclude that MR or chronic MR/GR has the same influence on action potential width. However, cycling corticosteroid levels may also have an influence since the action potential width was different in neurons from SHAM and ALD animals.

In conclusion, corticosteroids have an important role in maintaining the ratio of nonburst and burst firing pyramidal cells in hippocampal subfield CA3. The effects of corticosteroids on the cell-firing mode do not appear to be secondary to changes in the cell passive membrane of action potential properties. The effects of corticosteroids in subfield CA3 are distinct from their effects in subfield CA1. Therefore, corticosteroids modulate signal processing in the hippocampus by producing specific modulatory actions in the different hippocampal subfields.

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Fig. 1.

Membrane potential changes in a nonbursting (**A**) and bursting (**B**) firing cell. The cells received an injection of -700 and 400 pA current pulses, 300 ms in duration. Plots were generated from digitized data, therefore, action potentials appear truncated. **C** shows the action potentials of the bursting cell in **B** (arrow) at a higher scale. Notice the slow depolarizing envelope in the bursting cell.

Fig. 2.
Superimposed action potentials in a cell from an ADX (solid line) and HCT (broken line) animal. Each trace represents an average of five action potentials.

Table 1

Treatment groups

Treatment	Surgery	Implant	ACSF
SHAM	intact	none	1 nM corticosterone
ADX	adrenalectomy	none	no steroid
ALD	adrenalectomy	aldosterone (10 µg/h minipump)	3 nM aldosterone
HCT	adrenalectomy	200–300 mg corticosterone	100 nM corticosterone

Table 2

Number of nonbursting and bursting cells recorded from the different corticosterone treatment groups

	SHAM	ADX	ALD	HCT
Nonbursting	13	29	11	16
Bursting	19	10	15	10
Nonbursting, %	41	74	42	62

Proportion of nonbursting and bursting cells are different between treatment groups.

$\chi^2 = 9.592$, d.f. = 3, $p = 0.022$.

Table 3

The effects of corticosteroids on passive membrane electrophysiological properties

Treatment and cell type	RMP, mV	Resistance, M Ω	Tau, ms
SHAM			
NB	68.4 $\pm$ 1.4 (13)	50.1 $\pm$ 2.8 (13)	49.3 $\pm$ 4.2 (13)
B	72.0 $\pm$ 1.2 (19)	51.0 $\pm$ 1.9 (19)	49.3 $\pm$ 3.6 (19)
ADX			
NB	68.8 $\pm$ 0.9 (29)	51.6 $\pm$ 2.3 (29)	42.8 $\pm$ 2.4 (29)
B	69.3 $\pm$ 1.4 (10)	48.6 $\pm$ 3.0 (10)	53.4 $\pm$ 5.7 (10)
ALD			
NB	68.4 $\pm$ 1.8 (11)	45.2 $\pm$ 2.3 (11)	43.8 $\pm$ 5.4 (11)
B	71.7 $\pm$ 1.2 (15)	49.8 $\pm$ 2.9 (15)	48.1 $\pm$ 6.0 (15)
HCT			
NB	68.6 $\pm$ 1.5 (16)	54.7 $\pm$ 1.7 (16)	44.5B4.3(15)
B	68.6 $\pm$ 2.1 (10)	47.7 $\pm$ 4.8 (9)	55.1 $\pm$ 6.1 (9)

All values are reported as mean $\pm$ SEM. Figures in parentheses represent number. NB = Nonbursting; B = bursting.

Table 4

The effect of corticosteroids on action potential and fAHP properties

Treatment and cell type		Action potential		fAHP			
		threshold, mV	amplitude, mV	half-width ^a , μ s	baseline width ^b , ms	amplitude, mV	t $\frac{1}{2}$, ms
SHAM							
NB		50.9 $\pm$ 0.6 (13)	82.2 $\pm$ 1.4 (13)	963 $\pm$ 40 (13)	1.67 $\pm$ 0.06 (13)	7.8 $\pm$ 0.4 (13)	3.3 $\pm$ 0.3 (13)
B		50.8 $\pm$ 0.4 (19)	79.7 $\pm$ 0.8 (19)	926 $\pm$ 20 (19)	1.60 $\pm$ 0.04 (19)	7.7 $\pm$ 0.4 (17)	3.0 $\pm$ 0.2 (17)
ADX							
NB		51.4 $\pm$ 0.5 (29)	84.0 $\pm$ 1.1 (29)	975 $\pm$ 20 (28)	1.68 $\pm$ 0.04 (28)	7.8 $\pm$ 0.6 (26)	2.9 $\pm$ 0.2 (26)
B		51.7 $\pm$ 0.7 (10)	82.5 $\pm$ 0.5 (10)	940 $\pm$ 30 (10)	1.64 $\pm$ 0.07 (10)	6.7 $\pm$ 0.5 (9)	2.4 $\pm$ 0.2 (9)
ALD							
NB		51.9 $\pm$ 0.7 (11)	83.5 $\pm$ 1.3 (11)	877 $\pm$ 20 (11)	1.52 $\pm$ 0.04 (11)	7.2 $\pm$ 0.8 (11)	2.7 $\pm$ 0.2 (11)
B		50.1 $\pm$ 0.5 (14)	79.9 $\pm$ 1.4 (14)	862 $\pm$ 20 (14)	1.49 $\pm$ 0.05 (14)	7.6 $\pm$ 0.5 (15)	2.9 $\pm$ 0.3 (15)
HCT							
NB		52.0 $\pm$ 0.7 (16)	81.0 $\pm$ 1.3 (16)	896 $\pm$ 20 (16)	1.53 $\pm$ 0.04 (16)	9.0 $\pm$ 0.6 (14)	2.8 $\pm$ 0.2 (14)
B		51.7 $\pm$ 0.6 (9)	79.2 $\pm$ 1.4 (9)	896 $\pm$ 30 (9)	1.58 $\pm$ 0.06 (9)	8.4 $\pm$ 0.7 (10)	3.1 $\pm$ 0.4 (10)

All values are reported as mean $\pm$ SEM. Figures in parentheses represent number.

NB = nonbursting; B = bursting.

^aOne-way ANOVA $F = 5.400$; d.f. = 3, 116; $p = 0.002$ Student-Newman-Keuls $p < 0.05$. ADX (966 $\pm$ 20 μ s, $n = 38$) different from ALD (869 $\pm$ 10 μ s, $n = 25$) and HCT (896 $\pm$ 20 μ s, $n = 25$); SHAM (941 $\pm$ 20 μ s, $n = 32$) different from ALD.

^bOne-way ANOVA $F = 4.419$; d.f. = 3, 116; $p = 0.006$ Student-Newman-Keuls $p < 0.05$. ADX (1.67 $\pm$ 0.04 ms, $n = 38$) different from ALD (1.51 $\pm$ 0.03 ms, $n = 25$) and HCT (1.55 $\pm$ 0.03 ms, $n = 15$).

Table 5

The effect of corticosteroids on sAHP and accommodation properties

Treatment and cell type	sAHP amplitude, mV	sAHP $t_{1/2}$, ms	Accommodation, number of spikes
SHAM			
NB	11.8±0.9 (13)	1,001 B86 (6)	5.2±0.6 (13)
B	13.7±0.8 (19)	945±55 (11)	5.1±0.4 (19)
ADX			
NB	11.7±0.6 (28)	1,126±84 (19)	6.4±0.7 (26)
B	11.3±1.1 (10)	961±65 (9)	4.0±0.7 (9)
ALD			
NB	9.9±1.2 (11)	1,186±238 (10)	4.9±0.5 (11)
B	13.8±1.1 (15)	1,022±55 (12)	4.1±0.5 (15)
HCT			
NB	9.7±1.0 (13)	853±106 (11)	6.3±0.9 (14)
B	10.9±1.1 (9)	1,052±58 (6)	3.9±0.5 (10)

All values are reported as mean ± SEM. Figures in parentheses represent number of independent measures.

NB = Nonbursting; B = bursting.