

11-5-2012

Glial Cell Activity within the Ventrolateral Periaqueductal Gray of Male and Female Rats

Jean-Marc A. Sauzier

Georgia State University, jsauzier1@student.gsu.edu

Lori N. Eidson

Georgia State University, leidson1@student.gsu.edu

Follow this and additional works at: <http://digitalarchive.gsu.edu/caaurj>

Recommended Citation

Sauzier, Jean-Marc A. and Eidson, Lori N. (2012) "Glial Cell Activity within the Ventrolateral Periaqueductal Gray of Male and Female Rats," *Colonial Academic Alliance Undergraduate Research Journal*: Vol. 3, Article 2.

Available at: <http://digitalarchive.gsu.edu/caaurj/vol3/iss1/2>

This Article is brought to you for free and open access by Digital Archive @ GSU. It has been accepted for inclusion in Colonial Academic Alliance Undergraduate Research Journal by an authorized administrator of Digital Archive @ GSU. For more information, please contact digitalarchive@gsu.edu.

Colonial Academic Alliance Undergraduate Research Journal

Manuscript 1089

Glial Cell Activity Within The Ventrolateral Periaquiductal Gray of Male and Female Rats

Jean-Marc A. Sauzier

This Article is brought to you for free and open access by Digital Archive @ GSU. It has been accepted for inclusion in Colonial Academic Alliance Undergraduate Research Journal by an authorized administrator of Digital Archive @ GSU. For more information, please contact digitalarchive@gsu.edu.

GLIAL CELL ACTIVITY WITHIN THE VENTROLATERAL PERIAQUEDUCTAL GRAY
OF MALE AND FEMALE RATS

by

Jean-Marc A. Sauzier, Lori N. Eidson, Anne Z. Murphy

TABLE OF CONTENTS

LIST OF FIGURES.....vii

CHAPTER

1. INTRODUCTION.....	1
2. METHODS.....	2
3. RESULTS.....	5
4. DISCUSSION.....	5
5. FIGURES.....	7
6. REFERENCES.....	10

LIST OF FIGURES

Figure 1 Percent Maximum Possible Effect (%MPE) of varying doses of morphine in males vs. females Complete Freund’s Adjuvant (CFA) -treated rats7

Figure 2 Periaqueductal gray-rostral ventromedial medullary (PAG-RVM) descending pain pathway.....7

Figure 3 Florescent images of glial fibrillary acidic protein (GFAP) immunoreactivity within the periaqueductal gray (PAG) of male rats treated subcutaneously (sc) with either saline (5ml/kg) or morphine (5mg/kg).....8

Figure 4 Glial fibrillary acidic protein (GFAP) immunoreactivity within the periaqueductal gray (PAG) of male rats treated subcutaneously (sc) with either saline (5ml/kg) or morphine (5mg/kg).....8

Figure 5 Glial fibrillary acidic protein (GFAP) immunoreactivity within the periaqueductal gray (PAG) of male and female rats that were handled or treated with morphine (5mg/kg; sc).....9

Figure 6 Representative fluorescent images of glial fibrillary acidic protein (GFAP) immunoreactivity in the periaqueductal gray (PAG) of male and female rats that were handled or treated with morphine (5mg/kg;sc).....9

INTRODUCTION

Morphine is one of the most commonly prescribed drugs for the relief of prolonged pain. Morphine does not produce the same degree of analgesia in males as compared to females (Kepler *et al.*, 1989; Cicero *et al.*, 1996). Previous work in our lab has shown that females require 2-3 times more morphine to produce the same analgesic effect as males (Fig 1; Wang *et al.*, 2006.). To date, the mechanisms underlying sex differences in opiate responsiveness are unknown. The periaqueductal gray (PAG) is a brain region that has been shown to be important for the analgesic effects of morphine (Loyd and Murphy, 2008). The PAG sends extensive projections to the rostral ventromedial medulla (RVM) of the brainstem, which in turn sends descending projections to the dorsal horn of the spinal cord. The PAG-RVM-spinal cord pathway is an essential circuit for antinociception (A.I Basbaum *et al.*, 1978; H.L Fields *et al.*, 1991). These regions also contain a high density of mu opioids receptors (MOR) (Loyd *et al.*, 2007). Opioids modulate pain by binding to the mu opioid receptor in the ventrolateral PAG (vlPAG). vlPAG projection neurons excite cells in the rostral ventromedial medulla (RVM) that project to the dorsal horn of the spinal cord (Fig 2: Loyd and Murphy, 2008) where they inhibit incoming pain signals.

Recent studies suggest that glial cells are potent modulators of morphine-based analgesia. In particular, several studies have now shown that glial cells decrease the analgesic effect of opiates (Hao *et al.*, 2011; Wei *et al.*, 2012). The two primary glia cells involved in this phenomenon are astrocytes and microglia. Microglia are shown to be the first responders to even minor pathological changes in the CNS (Kreutzberg G.W., 1996). Activation of these cells is a key factor in the defense against brain tumors, infectious diseases, inflammation, ischaemia, trauma, and neurodegeneration (Kreutzberg G.W., 1996). Astrocytes have also been implicated in the

proinflammatory response to injury (Hao *et al.*, 2011; Wei *et al.*, 2012). Recent studies by our lab show that both microglia and astrocyte activity within the PAG increases in response to morphine (Fig 3 & 4: Eidson & Murphy; under review). As increased levels of glia activity are associated with decreased morphine analgesia, we tested the hypothesis that the sexually dimorphic effects of morphine were due to sex differences in glial cell activity within the vIPAG. If our hypothesis is correct, then administration of morphine to females should result in significantly higher levels of astrocyte activation as compared to males. For these studies we used immunohistochemistry to label glial fibrillary acidic protein (GFAP). GFAP is a commonly used marker of astrocyte activity, as it has been shown to correlate with a change in morphology and release of proinflammatory cytokines, indicative of an active phenotype (Raghavendra *et al.*, 2004) Sex differences in vIPAG glial cell activity may provide the biological bases for the sexually dimorphic effect of morphine. Given the strong evidence indicating that glial cell activity prevents morphine from being an effective analgesic, this research may lead to better treatment for females experiencing prolonged, chronic, or neuropathic pain.

Materials and Methods

Subjects. Aged matched adult male and female (2 months; 150-350g) Sprague-Dawley rats (Charles River Laboratories; USA) were procured and were allowed 7 days to acclimate to the new facility. Same-sex rats were pair-housed in separate rooms with 12:12 hour light: dark cycle (lights on at 8:00_{A.M.}). Vaginal lavages were taken, and vaginal cytology was analyzed daily (for 2-3 weeks) to ensure that females were cycling normally, and to determine the stage of the estrous cycle the rats were in on the day of sacrifice. Rats had access to food and water *ad*

libitum throughout the experiment. These studies were done in accordance with the Georgia State University Animal Care and Use Committee (IACUC).

Morphine Administration. Adult male and female Sprague Dawley rats were administered morphine sulfate (experimental group) in 0.9% sterile saline (5 mg/kg, sc; NIDA; Bethesda, MD) or were restrained in a similar manner (handled control). Following morphine administration, animals were placed back into their home cage until sacrifice.

Perfusion. The handled control and morphine groups were further assigned to two groups. The first group received a lethal dose of sodium pentobarbital (60mg/kg; ip) 15 mins after injection or handling. The second group was euthanized 60 mins following morphine administration. The animal was confirmed to be unconscious and was perfused transcardially with 200 ml of 0.9% sodium chloride containing 2% sodium nitrite solution to clear the blood from brain. Following the saline, brains were immediately fixed by perfusing 150 ml of 4% aqueous paraformaldehyde fixative solution containing 2.5% acrolein (Polysciences Inc.; Warrington, PA) into the heart. The fixative was rinsed using 200 ml of 0.9% sodium chloride/sodium nitrite solution.

Immediately after perfusion, brains were removed and stored in a 30% sucrose solution at 4 C until the time of sectioning (at least 24 hours). Brains were coronally sectioned using a freezing microtome (Leica 2000R) at 25µm and stored in cryoprotectant solution (Watson *et al.*, 1986) at -20 C until immunohistochemical staining.

Immunohistochemistry. Glial cell activity was localized to the vIPAG region. Tissue samples were rinsed in potassium phosphate buffer saline solution (KPBS) to remove cryoprotectant solution. Tissue was then incubated for 20 min in 1% sodium borohydride in KPBS. Astrocyte activity levels were determined by incubating the tissue samples in primary antibody, glial fibrillary acidic protein (GFAP), for one hour at room temperature followed by 48 hours at 4 C.

Rabbit α -GFAP (Abcam, 1:5000 for 3,3'-diaminobenzidine reaction, and 1:3000 for fluorescence) in KPBS containing 1% Triton-X solution. The primary antibody was washed out with KPBS, and the tissue was incubated for one hour in biotinylated goat anti-rabbit IgG secondary antibody (Jackson Immunoresearch, 1:600). Tissue was rinsed in KPBS and incubated in avidin-biotin peroxidase complex (ABC Elite Kit, Vector labs). Following rinsing in KPBS and sodium acetate solution (0.175M; pH 6.5), GFAP reactivity was visualized as a black chromagen reaction product using 3, 3'- diaminobenzidine solution containing nickel sulfate and 0.8% hydrogen peroxide in sodium acetate buffer. The reaction was terminated using three rinses of sodium acetate buffer. Sections were sorted to rostral-caudal levels, mounted onto gelatin-subbed slides, and allowed to air dry (at least 10 h). Tissue was dehydrated in a graded series of ethanol solutions, cleared in xylenes and cover-slipped using Permount.

Densitometry. Previous studies have shown that the PAG is not a homogenous structure (Van Bockstaele *et al.* 1991, Bandler *et al.*, 1994). In this study the densitometry of GFAP staining was determined for four rostro-caudal levels of PAG (Bregma -6.24, -6.72, -7.04, -8.00). GFAP immunoreactivity in the vPAG was compared across treatment groups using previously described semi-quantitative densitometry (loyd *et al.*, 2008, Laprairie *et al.*, 2009). Images, 12-bit grayscale, including the region of interest (ROI) were captured using a QImaging Retiga EXi CCD camera (Surrey, BC, Canada) and iVision Image analysis software (Biovision Technologies, Exton, PA). Grayscale values were inverted for each image so that higher values represent increased staining levels. Drawing tools were used in iVision to outline the ROI for data sampling, and using the “measure” function determined an average grayscale pixel value for the outlined area. Values were corrected for nonspecific binding by subtracting an adjacent measure of gray matter in the ROI to represent background. Densitometry values are presented

as mean \pm S.E.M. Analysis of variance (ANOVA) was used to test for significant main effects of sex (male, female), PAG level (Bregma -6.24 through -8.00); treatment (Handled, sc morphine 15 min, sc morphine 60 min) where relevant. $P \leq 0.05$ was considered significant for all analyses.

RESULTS

Male and female vPAG GFAP immunoreactivity increased in a similar pattern in response to morphine, with no significant differences noted at different Bregma levels within vPAG region (Fig 4). There was a significant main effect of treatment (handled v. morphine; ANOVA: $F_{(2, 24)} = 5.767$; $p = 0.009$). Post-hoc analysis revealed that 60 minutes of morphine increased vPAG astrocyte activity as compared with handled controls (t-test; $p = 0.0131$), and sc morphine 15 minute (t-test; $p = 0.0136$) in both males and females. There was no significant difference between the handled and sc morphine 15 groups (t-test; $p = 0.6204$). There was not a significant main effect of sex (ANOVA: $F_{(1, 24)} = 0.148$; $p = 0.7034$), and no significant interaction (ANOVA: $F_{(2, 24)} = 0.079$; $p = 0.9245$).

DISCUSSION

Recent studies suggest that glial cells are potent modulators of morphine-based analgesia, and in particular, decrease the analgesic effect of opiates (Raghavendra *et al.*, 2002, Wei *et al.*, 2008, Watkins *et al.*, 2001). Morphine acts through the PAG-RVM pathway to produce analgesia. The results of our study indicate that morphine does not differentially activate vPAG astrocytes in male and female rats. Indeed, both males and females showed a similar activation pattern in response to morphine. Administration of morphine resulted in a 2 fold increase in activation at 60 mins as compared to handled. Consistent with previous work done in our lab, morphine causes increased vPAG glial cell activity in males (Eidson & Murphy; under review). Our

hypothesis that female rats have increased glial cell activation in the vIPAG as compared with males was not supported. In future studies, microglial cell number and function will be determined within the PAG. Microglia have also been shown to inhibit morphine analgesia (Guo *et al*, 2012).

Morphine causes the activation of glia and leads to the release and upregulation of proinflammatory cytokines (Johnston *et al.*, 2004) that oppose morphine analgesia (Raghavendra *et al.*, 2002, Watkins *et al.*, 2001, Hutchinson *et al.*, 2008). Cytokines, or more specifically tumor necrosis factor alpha (TNF α), have been shown to suppress morphine analgesia (Hao *et al.*, 2011). Studies of the role of cytokines in response to morphine analgesia in both the male and female models could also prove to be beneficial in better understanding mechanisms of vIPAG glial cell activity.

FIGURES

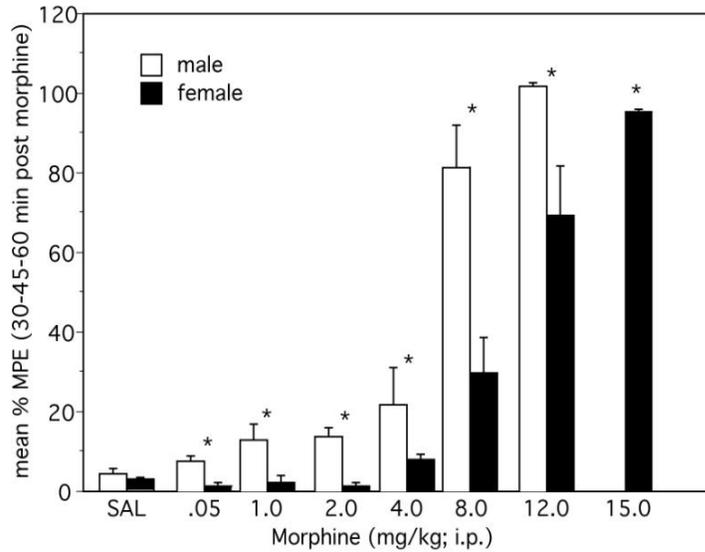


Fig. 1. The antinociceptive response to different morphine dosage, expressed as %MPE, in male and female CFA-treated rats (N = 54). PWL were measured for each dosage. A light cut off of 20 sec was implemented to reduce possible harm to animals. $P < 0.05$ for male-female comparison was used.

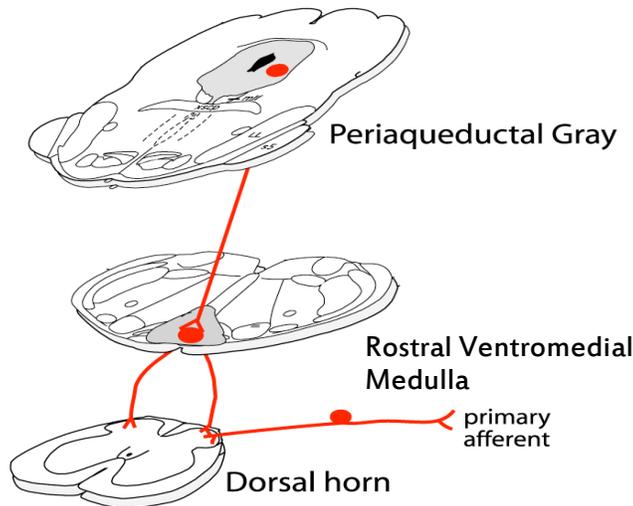


Fig. 2. A schematic of the neuronal projections from the midbrain periaqueductal gray to the brainstem RVM and spinal cord dorsal horn illustrating the descending pain pathway.

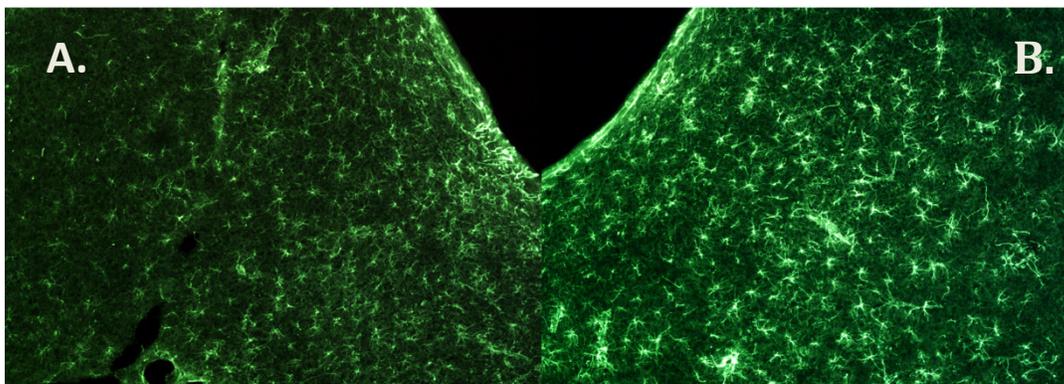


Fig. 3. Glial fibrillary acidic protein (GFAP) fluorescent-immunoreactive vI-PAG of male rats. Animals were either administered **A.** s.c saline (5ml/kg) or **B.** s.c morphine (5mg/kg).

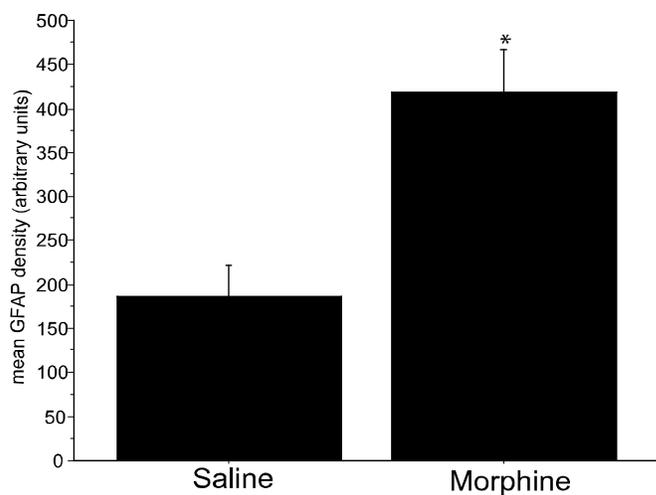


Fig. 4. Glial fibrillary acidic protein (GFAP) -immunoreactive cells in the midbrain periaqueductal gray (PAG) of male rats. Values are expressed as the mean \pm SEM percentage of all levels. Animals were either administered s.c saline (5ml/kg) or s.c morphine (5mg/kg).

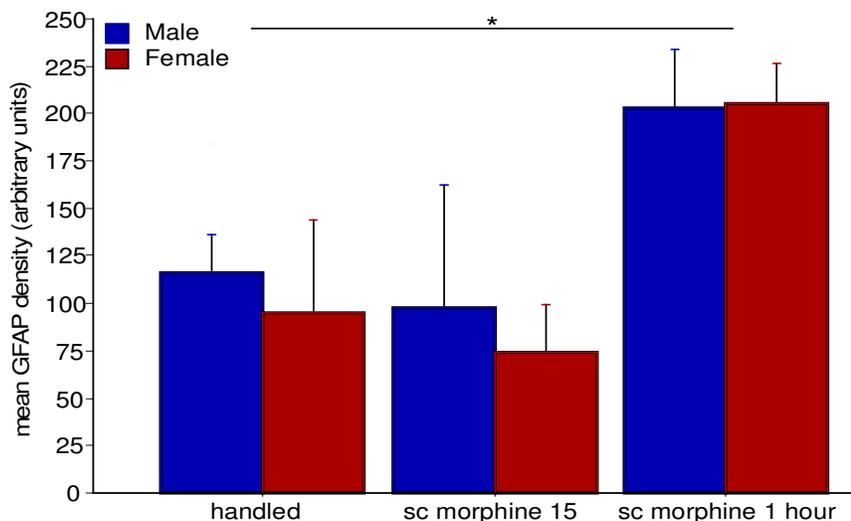


Fig. 5. Glial fibrillary acidic protein (GFAP) -immunoreactive cells in the midbrain periaqueductal gray (PAG) of male and female rats. Values are expressed as the mean \pm SEM percentage of all levels. Animals were either administered s.c morphine (5mg/kg) or were handled. Both treatment groups were perfused either 15 min or 30 min after treatment.

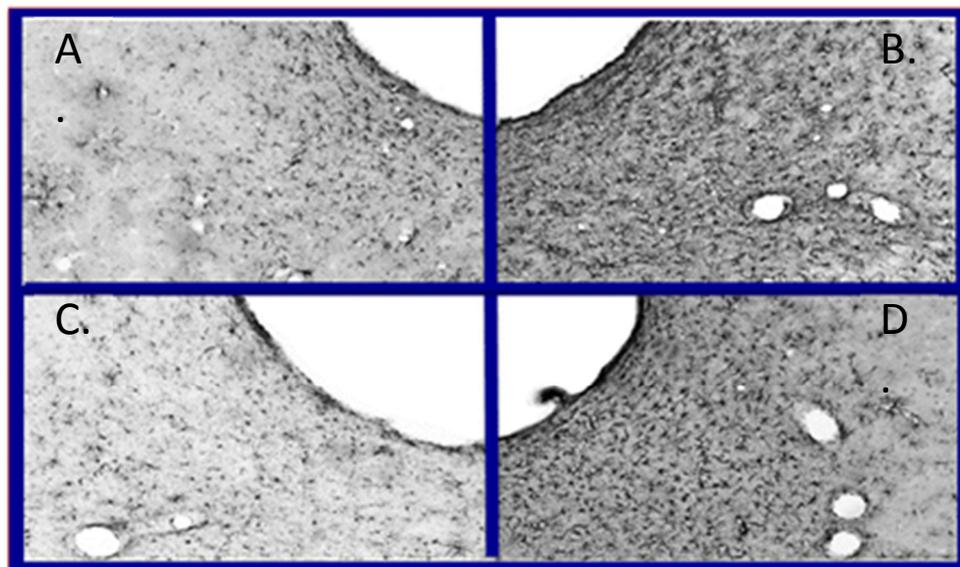


Fig. 6. Glial fibrillary acidic protein (GFAP) immunoreactive cells in the midbrain periaqueductal gray (PAG). Representative PAG images from Sprague-Dawley rats. **A.** Handled male **B.** s.c morphine (5mg/kg) male **C.** handled female **D.** s.c morphine (5mg/kg) female. Animals were perfused 15 or 30 min after treatment.

REFERENCES

- Bandler R. and Shipley M.T. 1994. "Columnar organization in the midbrain periaqueductal gray: modules for emotional expression?" *Trends Neurosci.* 17, 9: 379-389.
- Basbaum A.I. and Fields H.L. 1978. "Endogenous pain control mechanisms: review and hypothesis." *Annals of Neurobiology*, 4, 5: 451-462.
- Cicero T.J., Nock B. and Meyer E.R. 1996. "Gender-related differences in the antinociceptive properties of morphine." *J. Pharmacol. Exp. Ther.* 279: 767-773.
- Fields H.L., Heinricher M.M., and Mason P. 1991. "Neurotransmitters in nociceptive modulatory circuits." *Annu. Rev. Neurosci.* 14: 219-245.
- Guo W., Wang H., Zou S., Dubner R., and Ren K. 2012. "Chemokine signaling involving chemokine (c-c motif) ligand 2 plays a role in descending pain facilitation." *J. Neurosci.* 28: 2; 193-207.
- Hao S., Liu S., Zheng X., Zheng W., Ouyang H., Mata M. and Fink D.J. 2011. "The role of TNF α in the periaqueductal gray during naloxone- precipitated morphine withdrawal in rats." *Neuropharm.* 36: 664-676.
- Hutchinson M.R., Coats B.D., Lewis S.S., Zhang Y., Sprunger D.B., Rezvani N., Baker E.M., Jekich B.M., Wieseler J.L., Somogyi A.A., Martin D., Poole S., Judd C.M., Maier S.F., Watkins L.R. 2008. "Proinflammatory cytokines oppose opioid-induced acute and chronic analgesia." *Brain Beh Immun.* 22, 8: 1178-1189.
- Johnston I.N., Milligan E.D., Wieseler-Frank J., Frank M.G., Zapata V., Campisi J., *et al.* 2004. "A role for proinflammatory cytokines and fractalkine in analgesia, tolerance, and subsequent pain facilitation induced by chronic intrathecal morphine." *J. Neurosci.* 24: 7353-7365.
- Kepler K. L., Kest B., Paul D., Kiefel J.M., Cooper M.L. and Bodnar R. J. 1989. "Roles of gender, gonadectomy and estrous phase in the analgesic effects of intracerebroventricular morphine in rats." *Pharmacol. Biochem. Behav.* 34: 119-127.
- Kreutzberg G.W. 1996. "Microglia: a sensor for pathological events in the CNS." *Trends Neurosci.* 19, 8: 312-318.
- Laprairie J.L., and Murphy A.Z. 2009. "Neonatal injury alters adult pain sensitivity by increasing opioid tone in the periaqueductal gray." *Front Behav. Neurosci.* 3: 31.
- Loyd D.R., Morgan M.M., and Murphy A.Z. 2008. "Sexually dimorphic activation of the periaqueductal gray- rostral ventromedial medullary circuit during the development of tolerance to morphine in the rat." *Eur. J. Neurosci.* 27: 1517-1524.

Lloyd D.R. and Murphy A.Z. 2008. "The role of the periaqueductal gray in the modulation of pain in males and females: are the anatomy and physiology really that different?" *Neural Plasticity*. vol. 2009. Article ID 462879, 12 pages.

Raghavendra V. and Deleo J.A. 2004. "The role of astrocytes and microglia in persistent pain." *Advances in Molecular and Cell Biology*, 31: 951–966.

Raghavendra V., Rutkowski M.D., and Deleo J.A. 2002. "The role of spinal neuroimmune activation in morphine tolerance/hyperalgesia in neuropathic and sham-operated rats." *J. Neurosci.* 22: 9980-9989.

Van Bockstaele E.J., Aston-Jones G., Pieribone V.A., Ennis M., and Shipley M.T. 1991. "Subregions of the periaqueductal gray topographically innervate the rostral ventral medulla in the rat." *J. Comp. Neurol.* 309, 3: 305-327.

Wang, X., Traub, R.J. and Murphy, A.Z. 2006. "Persistent pain model reveals sex difference in morphine potency." *Am. J. Physiology*, 291: 300-306.

Watkins L.R., Milligan E.D., and Maier S.F. 2001. "Spinal cord glia: new players in pain." *Pain*. 93, 3: 201-205.

Watson R.E., Wiegand S.J., Clough R.W., Hoffman G.E. 1986. "Use of cryoprotectant to maintain longterm peptide immunoreactivity and tissue morphology." *Peptides*. 7: 155-159.

Wei F., Guo W., Zou S., Ren K. and Dubner R. 2008. "Supraspinal glial- neuronal interactions contribute to descending pain facilitation." *J. Neurosci.* 28: 10482-10495.