--- **Original Article** ---

Study of 5HT$_3$ and HT$_4$ Receptor Expression in HT29 Cell Line and Human Colon Adenocarcinoma Tissues

Ramin Ataee Pharm D*, Soheila Ajdary PhD•***, Mehdi Rezayat PhD*,
Mohammad Ali Shokrgozar PhD***, Shadab Shahriari MSc**,
Mohammad Reza Zarrindast PhD*

Background: Serotonin (5HT) has been shown to be a mitogenic factor in several carcinomas. Its mitogenic effect is elicited through a wide range of 5HT receptor subtypes. In this study, the effects of 5HT, 5HT$_3$ (1-phenylbiguanide hydrochloride) and 5HT$_4$ (cisapride) agonists in promoting the growth of the HT29 cell line and the growth-inhibition effect of the 5HT$_3$ receptor antagonist (Y-25130 hydrochloride) and 5HT$_4$ receptor antagonist (RS 23597-190) were investigated. The expressions of 5HT$_3$ and 5HT$_4$ receptors in human colon cancer tissues and the HT29 cell line were studied.

Methods: The growth-promoting and growth-inhibition effects of 5-HT, 5HT$_3$ and 5HT$_4$ agonists and antagonists on the HT29 cell line were studied using MTT assay. Receptor expression has been demonstrated by western blotting.

Results: The results showed that 5HT, 5HT$_3$, and 5HT$_4$ agonists caused significant proliferation of HT29 cells. 5HT$_3$ and 5HT$_4$ receptor antagonists had an inhibitory effect on the growth of these cells. Western blot analysis gave bands from colon tissue extracts and the HT29 cell line.

Conclusion: The results indicate which 5HT$_3$ and 5HT$_4$ receptors are significantly expressed in both colon cancer tissue and the HT29 cell line. Expression for the 5HT$_3$ receptor is more potent. Furthermore, 5HT plays a mitogenic role in colon cancer cells and antagonists of 5HT$_3$, and 5HT$_4$ receptors can inhibit cancer cell growth.

Archives of Iranian Medicine, Volume 13, Number 2, 2010: 120 – 125.

Keywords: Colon adenocarcinoma • HT29 cell • serotonin • 5HT$_3$ and 5HT$_4$ receptors

Introduction

Colorectal cancer is one of the major causes of cancer-related deaths in the world. Over the last decade, much progress has been made in the treatment of this malignancy and new chemicals have been introduced. The survival of people with metastatic colorectal cancer has improved with new therapeutics. Recently, selective serotonin reuptake inhibitors (SSRIs) have been suggested as preventive agents for people at high risk of developing colorectal cancer,[1] and is based on reports indicating that SSRIs could decrease the risk of colorectal cancer in humans.[2] Laboratory studies have shown that Fluoxetine, a novel SSRI drug, at doses of 10 – 100 µM may reduce the growth of cancer cells *in vitro*. This effect may be mediated by increasing serotonin levels in the peripheral nerve endings of the gastrointestinal tract.[3] However; other reports suggest that SSRIs may induce mammary tumors in animals and breast cancer in humans.[4, 5]

Serotonin (5-hydroxytryptamine; 5HT) is a neurotransmitter that mediates a wide variety of physiological effects (both peripherally and centrally) by binding to multiple receptor subtypes. The major sites of 5HT synthesis and storage are located in the periphery, the gut enterochromaphin cells and blood platelets, respectively. The great

Authors' affiliations: *Department of Pharmacology, School of Medicine, Tehran University of Medical Sciences, **Department of Immunology, Tehran University of Medical Sciences, ***Department of Cell Bank, Pasteur Institute of Iran, Tehran, Iran.
•**Corresponding author and reprints:** Soheila Ajdary PhD, Department of Immunology, Pasteur Institute of Iran, Tehran, Iran.
Tel: +98-216-696-8847, Fax: +98-216-696-8847
E-mail:sohary@yahoo.com
Accepted for publication: 21 October 2009

diversity of 5HT functions is due to different 5HT receptors and the pharmacological complexity of these receptors, reflecting the second messenger system to which the receptors are coupled. The 5HT family, including $5HT_1$ and $5HT_5$ subtypes of receptors negatively interact with adenylate cyclase and the $5HT_2$ subfamily of receptors is coupled to the activation of phospholipase C-β. Adenylate cyclase is activated by the $5HT_4$, $5HT_6$, and $5HT_7$ subtypes of receptors.[6]

$5HT_3$ receptors are cation channels that tend to depolarize the membrane when activated.[7] $5HT_3$ receptors contain four transmembrane domains and exist as homo- or hetero-pentamers in the membrane. Two $5HT_3$ receptor subunits have been identified: $5HT_{3A}$ and $5HT_{3B}$.[8,9] The $5HT_{3A}$ subunit can form a functional channel as a homo-pentamer, but the $5HT_{3B}$ subunit alone does not. In addition to two known $5HT_3$ subunits, two splice variants of $5HT_{3A}$ have been identified by Brüss et al.[10] which further increases the functional diversity of these receptors. It is possible that additional, undiscovered $5HT_3$ receptor subunits exist.

The $5HT_4$ receptor was first characterized in mouse collicular neurons.[11] It is also found in the hippocampus and in peripheral tissues such as the guinea pig ileum, rat esophagus, and human atrium.[12] The $5HT_4$ receptor has been suggested to contribute to tumor cell progression by secretion of hormones and other growth factors.[13]

$5HT_3$ receptor is expressed in the enteric nervous system[14,15] and plays an important role in enteric physiology. Although there is some evidence regarding the mitogenic effects for 5HT in certain malignancies such as breast, prostate, and bladder cancer[16–18]; to date, however, there have been no studies specifically assessing the role of 5HT and expression of $5HT_3$ and $5HT_4$ receptors in colon cancer. There are some reports concerning the mitogenic role of serotonin in colon cancer. For example, in one study, the influence of serotonin in dimethylhydrazine-induced adenocarcinoma of the colon has been reported.[19,20] However, few studies have been conducted that examine the possible role of $5HT_3$ and $5HT_4$ receptors' agonists and antagonists in tumor regulation. In the present study we have determined the effect of 5HT, $5HT_3$, and $5HT_4$ agonists and antagonists on the proliferation of the HT29 human colon adenocarcinoma cell line. We also studied the expression of 5HT receptor subtypes 3 and 4 in this cell line and in colon cancer tissue.

Materials and Methods

Tissues and cell line

Human colon cancer tissue samples were obtained during surgery from five patients (Imam Hospital, Tehran, Iran). Tissue samples were used for western blot analysis.

The HT29 cell line was kindly provided by the National Cell Bank of Iran (NCBI), Pasteur Institute of Iran. It must be noted that HT29 is a current human cell line with potent metastatic potential which has been widely used in colorectal carcinoma studies. With respect to this and according to other studies,[21] we selected this cell line for our study. The cells were maintained in exponential growth phase in 25-cm^2 flasks in RPMI 1640 (Gibco, Germany) medium supplemented with 10% heat-inactivated fetal calf serum (Gibco, Germany), 2 mM glutamine, 100 U/mL penicillin and 100 µg/mL streptomycin (all from Sigma, Germany) in a humidified atmosphere of 5% CO_2 at a constant temperature of 37°C. Cells were split when they reached a confluency of approximately 90 – 95%.

MTT proliferation assay

HT29 cells were washed with Phosphate buffer saline (PBS) and harvested with a 0.5% trypsin (Sigma, Germany) solution at 50 – 60% confluency. Cells were then added to wells at a density of 10^4 cells/well in a 96-well plate to a final volume of 100 µL/well. After 24 hours of incubation at 37°C in a 5% CO_2 atmosphere, the culture medium was replaced with 200 µL fresh culture medium containing 5HT hydrochloride (Sigma,Germany),1-phenylbiguanide hydrochloride ($5HT_3$ agonist), cisapride ($5HT_4$ agonist), Y-25130 hydrochloride ($5HT_3$ antagonist), or RS 23597-190 ($5HT_4$ antagonist; all from Tocris Laboratories, UK) at concentrations of: 3.125, 6.25, 12.5, 25, 50, and 100 µM. Cells cultured solely in media served as negative controls. After 48 hours of incubation at 37°C in a 5% CO_2 atmosphere, the culture medium was removed and 8 µL MTT reagent (diluted in PBS at a concentration of 4 mg/mL; Sigma, Germany) was added to 50 µL of fresh culture medium at a final concentration of 0.55 mg/mL. The optimum incubation period time was determined in a pilot study.

After incubating the plates again for a 4 hour at 37°C in 5% CO_2 atmosphere, the resulting formazan product was resolved in 50 µL dimethyl sulfoxide (Merck Germany) and measured

spectrophotometrically at 570 nm (with a reference wavelength of 690 nm). The mitogenic effect was determined using the following formula: (mean absorbance (570 – 690 nm) of treated wells/mean absorbance (570 – 690 nm) of control wells) ×100.

Results were expressed as the mean of five assays (three replicates for each concentration of each assay).

Protein extraction

HT29 cells were harvested with a 0.5% trypsin solution at 90 – 95% confluency and resuspended in lysis buffer containing a complete protease inhibitor (Roche, Germany), 1% SDS, tris 50 mM, pH 7.4; 0.5% sodium deoxycholate (Sigma, Germany). The lysate was incubated for 30 minutes at 4°C. Subsequently, the suspension was centrifuged at 12000 g for 20 minutes at 4°C and supernatant was kept at -70°C.

Frozen samples of colon cancer tissue and rat brain as positive controls were homogenized in lysis buffer and the proteins were extracted as described above. Protein concentrations of supernatants were determined by the Bradford assay, with BSA as a standard.

Western blot analysis

Equal amounts of protein samples were heated at 100°C for 5 minutes in 6× SDS gel-loading buffer consisting of 375 mM Tris-HCl (pH 6.8), 12% SDS, 60% glycerol, 30% 2-mercaptoethanol, and 0.6% bromophenol blue. Proteins were separated by SDS-polyacrylamide gel electrophoresis (SDS-PAGE) on 5% stacking and 10% separating gels. Proteins were then transferred to an Immobilon-P PVDF membrane (BioRad, Germany). Nonspecific binding sites were blocked by 1% bovine serum albumin in PBS (BSA-PBS). The membrane was subsequently incubated for 1 hour with goat anti-5HT3 or goat anti-5HT4 antibody (Santa Cruz, USA). After incubation with antibody, the membrane was washed three times, for 15 minutes each, with 50 mL of PBS containing 0.05% tween 20 (PBS-T). The membrane was then incubated for 1 hour with peroxidase conjugated donkey anti-goat IgG (Santa Cruz, USA) and was washed as mentioned above. The membrane was developed with diaminobenzidine (DAB; Sigma, Germany). Normal marginal tissues from the same patients were used as negative controls.

Statistical analysis

The results were expressed as the mean±SD.

Statistical differences were evaluated by one-way ANOVA. $P \leq 0.05$ was considered significant.

Results

MTT assay

The MTT assay was used to determine the effects of 5HT, $5HT_3$, and $5HT_4$ receptor agonists and antagonists on human colon cancer cell line proliferation. Cells were treated with increasing concentrations of drugs and the numbers of cells after incubation were determined spectrophotometrically using the MTT reagent.

As shown in Figure 1, 5HT, $5HT_3$ agonist (1-phenylbiguanide hydrochloride), and the $5HT_4$ agonist (cisapride) caused a dose dependent proliferation of HT29 cells after 48 hours incubation. The maximum proliferation was at a
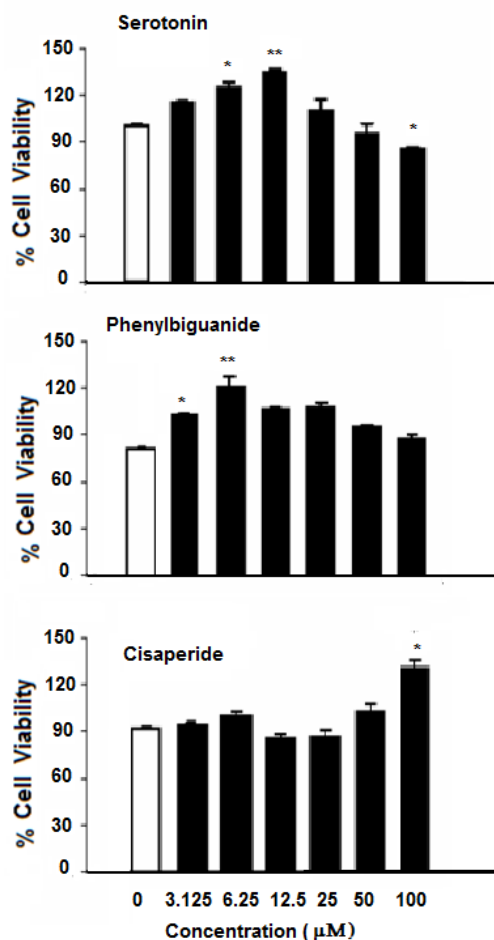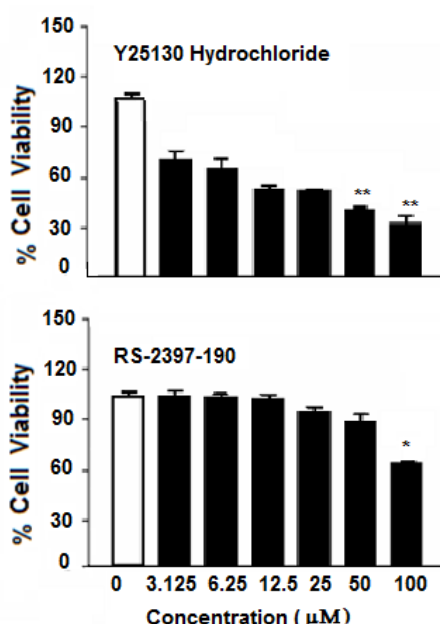

Figure 1. Effects of 5HT, $5HT_3$, and $5HT_4$ agonists on human colon cell proliferation. Cells were treated with increasing concentrations of drugs and cell proliferation was determined by MTT proliferation assay. Results represent the mean±SD values. (*$P \leq 0.05$, **$P \leq 0.01$)

5HT concentration of 12.5 μM ($P \leq 0.01$). 5HT$_3$ agonists significantly stimulated the growth of cells at concentrations of 3.125 μM ($P \leq 0.05$) and 6.25 μM ($P \leq 0.01$). Stimulation of cell growth with 5HT$_4$ receptor agonist (cisapride) needed a higher concentration of related agonist. A significant growth stimulatory effect was observed at 100 μM ($P \leq 0.05$).

5HT$_3$ receptor antagonist (Y-25130 hydrochloride) and 5HT$_4$ antagonist (RS 23597-190) had dose-dependent inhibitory effects on cell growth (Figure 2). The 5HT$_3$ antagonist significantly inhibited proliferation of HT29 cells at concentrations of 50 and 100 μM ($P \leq 0.01$). The 5HT$_4$ receptor antagonist inhibited proliferation of the colon cell line at only the 100 μM concentration ($P \leq 0.01$).

Western blot analysis

Western blot analysis of HT29 cells and human colorectal tumor tissues has confirmed expression of 5HT$_3$ and 5HT$_4$ receptor proteins. At least three different western blots were performed with total proteins extracted from each sample. Polyclonal anti-5HT$_3$ IgG recognized a single band of approximately 48 kDa, and anti-5HT$_4$ IgG showed a band of approximately 44 kDa in the HT29 cell line and cancer tissues. Proteins isolated from the rat

brain (positive control) revealed similar bands to those of proteins isolated from the HT29 cell line and human colorectal tumor tissues (Figure 3).

Discussion

In the present study, for the first time, we have demonstrated that 5HT$_3$ and 5HT$_4$ serotoninergic receptors are expressed in a human colon cancer cell line (HT29) and in the tumor tissues from patients with colon carcinoma.

Moreover, MTT proliferative assays which measure cell viability through the reductive activity of mitochondria revealed that 5HT, 5HT$_3$, and 5HT$_4$ agonists stimulate HT29 cell proliferation. It has been shown that 5HT acts as a growth factor for several types of non-tumor and tumor cells including the choriocarcinoma, breast, prostate, and bladder cancer cell lines.[16–18,22] Given the wide distribution of 5HT$_3$ and 5HT$_4$ receptors in the alimentary tract, we were interested to determine if the mitogenic effect of 5HT was mediated by these receptors. The

Figure 3. Western blot analysis showing expression of 5HT$_3$ and 5HT$_4$ receptors in HT29 cell line and human colon cancer tissue. Polyclonal anti-5HT$_3$ IgG recognized a single band of approximately 48 kDa (A), and anti-5HT$_4$ IgG showed a band of approximately 44 kDa in HT29 cell line and cancer tissues.
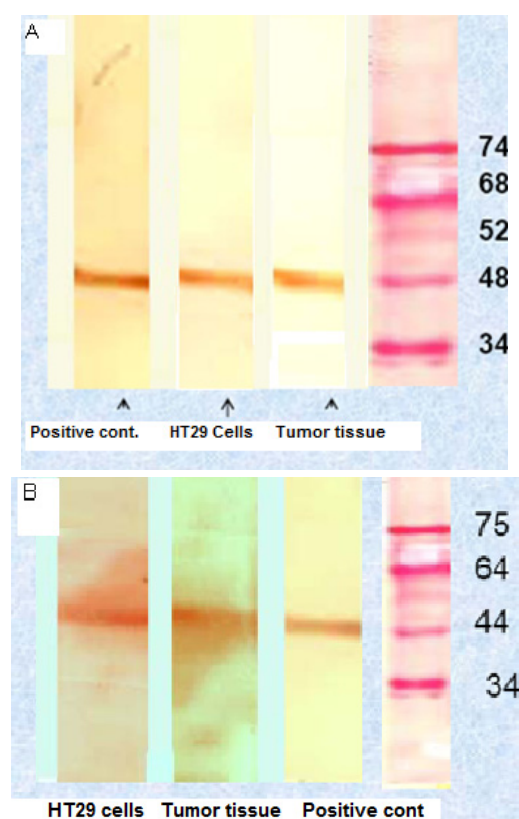
Figure 2. Antagonist to receptor 5HT$_3$ (Y-25130 hydrochloride) significantly inhibited proliferation of HT29 cells at concentrations of 50 and 100 μM ($P \leq 0.01$). 5HT$_4$ antagonist (RS 23597-190) inhibited proliferation of colon cell line at 100 μM ($P \leq 0.01$)

proliferation of the HT29 cell line in response to $5HT_3$ and $5HT_4$ agonists suggested that the mitogenic effect of 5HT on this cell line was mediated in part by $5HT_3$ and $5HT_4$ receptors. Siddiqui et al. have shown that $5HT_1$ but not $5HT_2$ and $5HT_3$ exert cell growth in bladder cancer cells.[16] This effect is mediated by $5HT_2$ in a breast cancer cell line.[17] Although $5HT_1$ and $5HT_2$ receptors are known as mitogenic receptors, the mitogenic activity of $5HT_3$ receptors is a novel finding. The mitogenic effect of 5-HT via a $5HT_{2A}$ receptor has been described as being mediated by different signal transduction pathways, including the Jak/STAT[23] and Erk/MAPK activation.[24,25] The signal transduction pathway of the mitogenic effect of $5HT_3$ receptor remains to be revealed.

Likewise, the $5HT_4$ receptor agonist results in HT29 cell line proliferation. Receptor subtype 4 has been shown to stimulate hormone secretion. The agonist to $5HT_4$ stimulates cortisol secretion in patients with adrenal tumors and IGF-1 secretion in mice fibroblasts.[26] It has been suggested that $5HT_4$ may contribute to tumor cell progression by stimulating hormonal secretion and other growth factors, probably via activation of adenylate cyclase.[27]

Moreover, $5HT_3$ and $5HT_4$ antagonists inhibited HT29 cell growth. In line with our findings, the antiproliferative effect of RS 23597-190 ($5HT_4$ antagonist) has also been reported in the DU145 prostate cancer cell line.[28] However, the $5HT_3$ and $5HT_4$ antagonists had no significant inhibitory effects on cell growth of the bladder cancer cell line 16 and PC3 prostate cancer cells.[16,29]

To further confirm the role of $5HT_3$ and $5HT_4$ receptors in regulation of the colon cell line growth, western blot analysis was carried out. In the present study western blot analysis identified $5HT_3$ and $5HT_4$ receptor proteins in the HT29 colon cell line and colon cancer tissues. A similar profile with HT29 cells, colon tumor tissues, and rat brain demonstrated major protein bands at 48 and 44 kDa for $5HT_3$ and $5HT_4$ receptors, respectively. Also this immunoblot expression for the $5HT_3$ receptor was completely significant when compared with the negative control (normal human marginal tissue) and as strong as the positive control (brain tissue). However, for the $5HT_4$ receptor, this expression was mild. According to other protein expression studies, it has been previously demonstrated that the $5HT_2$ receptor expressed profoundly in breast cancer.[17] Other western blot and immunohistochemistry studies have shown that $5HT_{1A}$ and $5HT_{1B}$ receptors

expressed in bladder and prostate cancer.[16,18] In those studies, immunohistochemistry assays showed expression of 5HT receptors in the cell membrane and cytoplasm of colon epithelial cells which are the site of localization of the G-protein coupled receptors (GPCR) as 5HT receptors. Therefore, our study as long as previous researches, describes the expression of 5HT receptors in cancer. But further studies are needed to clarify the pattern of these receptor expressions.

In summary, our results demonstrate for the first time that the $5HT_3$ and $5HT_4$ receptors are expressed in both human colon cancer tissue and cell line HT29. This expression for the $5HT_3$ receptor is much stronger and more important than $5HT_4$. Our data also show that 5HT, in part via the $5HT_3$ and $5HT_4$ receptors, has a mitogenic effect on HT29 cell proliferation.

Acknowledgments

References

1 Biasco G, Pantaleo M, Palassini E, Labianca R. Targeted therapy in colorectal cancer: do we know enough? *Dig Liver Dis.* 2005; **38**: 71 – 77.

2 Warning X, Hani T, Stan Sh. Use of antidepressants and risk of colorectal cancer: a nested case-control *study. Lancet Oncol.* 2006; **7**: 301 – 308.

3 Yue CT, Liu YL. Fluoxetine increase extracellular levels of 3-methoxy-4-hydroxy phenylglycol in culture*d colo320 DM c*ells. *Cell Biochem.* 2005; **23**: 109 – 114.

4 Sharpe CR, Collet P, Belzile E, Hanley JA, Boivin JF. The effects of tricyclic antidepressants on breast cancer risk. *Br J Cancer.* 2002; **86**: 92 – 97.

5 Clark L, Hilakivi WA, Lippman ME. DMBA induced mammary tumor growth in rats exhibiting increased or decreased ability to cope with stress due to early postnatal handling or antidepressant treatment. *Physiol. Behav.* 1993; **54**: 229 – 236.

6 Raymond JR, Mukhin YV, Gelasco A, Turner J, Collinsworth G, Gettys TW, et al. Multiplicity of mechanisms of serotonin receptor signal transduction. *Pharmacol Ther.* 2001; **92**: 179 – 212.

7 Peters JA, Malone HM, Lambert JJ. Recent advances in the electrophysiological characterization of 5HT3 receptors. *Trends Pharmacol Sci.* 1992; **13**: 391 – 397.

8 Maricq AV, Peterson AS, Brake AJ, Myers RM, Julius D. Primary structure and functional expression of the 5HT3 receptor, a serotonin-gated ion channel. *Science.* 1991; **254**: 432 – 437.

9 Davies PA, Pistis M, Hanna MC, Peters JA, Lambert JJ,

Hales TG, et al. The 5-HT3B subunit is a major determinant of serotonin-receptor function. *Nature.* 1999; **28:** 359 – 363.

10 Brüss M, Barann M, Hayer-Zillgen M, Eucker T, Göthert M, Bönisch H, et al. Modified 5-HT3A receptor function by co-expression of alternatively spliced human 5-HT3A receptor isoforms. *Arch Pharmacol.* 2000; **362:** 392 – 401.

11 Dumuis A, Bouhelal R, Sebben M, Cory R, Bockaert J. A nonclassical 5-hydroxytryptamine receptor positively coupled with adenylate cyclase in the central nervous system. *Mol Pharmacol.* 1988; **34:** 880 – 887.

12 Bockaert J, Fozard JR, Dumuis A, Clarke DE. The 5-HT4 receptor: a place in the sun. *Trends Pharmacol Sci.* 1992; **13:** 141 – 145.

13 Hoyer D, Hannon JP, Martin GR. Molecular, pharmacological and functional diversity of 5-HT receptors. *Pharmacol Biochem Behav.* 2002; **71:** 533 – 554.

14 Johnson DS, Heinemann SF. Detection of 5-HT3R-A, a 5-HT3 receptor subunit, in submucosal and myenteric ganglia of rat small intestine using *in situ* hybridization. *Neurosci Lett.* 1995; **184:** 67 – 70.

15 Nagakura Y, Kontoh A, Tokita K, Tomoi M, Shimomura K, Kadowaki M. Combined blockade of 5-HT3- and 5-HT4-serotonin receptors inhibits colonic functions in conscious rats and mice. *J Pharmacol Exp Ther.* 1997; **281:** 284 – 290.

16 Siddiqui EJ, Shabbir MA, Mikhailidis DP, Mumtaz, FH, Thompson C. The effect of serotonin and serotonin antagonists on bladder cancer cell proliferation. *BJU International.* 2006; **97:** 634 – 639.

17 Sonier B, Arseneault M, Lavigne C, Ouellette RJ, Vaillancourt C. The 5HT2A serotoninergic receptor is expressed in the MCF-7 human breast cancer cell line and reveals a mitogenic effect of serotonin. *Biochem Biophys Res Commun.* 2006; **343:** 1053 – 1059.

18 Dizeyi N, Bjartell A, Nilsson E, Hansson J, Gadaleanu V, Cross N, et al. Expression of serotonin receptors and role of serotonin in human prostate cancer tissue and cell lines. *The Prostate.* 2004; **59:** 328 – 336.

19 Tutton PJ, Barkla DH. The influence of serotonin on the mitotic rate in the colonic crypt epithelium and in colonic adenocarcinoma in rats. *Clin Exp Pharmacol Physiol.* 1978; **5:** 91 – 94.

20 Tutton PJ, Barkla DH. Evaluation of the cytotoxicity of dihydroxytryptamines and 5-hydroxytryptamine antagonists as cytotoxic agents in dimethylhydrazine-induced adenocarcinomata. *Cancer Chemother Pharmacol.* 1978; **1:** 209 – 213.

21 Pourgholami MH, Akhter J, Wang L, Lu Y, Morris DL. Antitumor activity of albendazole against the human colorectal cancer cell line HT-29: *in vitro* and in a xenograft model of peritoneal carcinomatosis. *Cancer Chemother Pharmacol.* 2005; **55:** 425 – 432.

22 Sonier B, Lavigne C, Arseneault M, Ouellette R, Vaillancourt C. Expression of the 5-HT2A serotoninergic receptor in human placenta and choriocarcinoma cells: mitogenic implications of serotonin. *Placenta.* 2005; **26:** 484 – 490.

23 Guillet-Deniau I, Burnol AF, Girard J. Identification and localization of skeletal muscle serotonin 5-HT2A receptor coupled to the Jak/STAT pathway. *J Biol Chem.* 1997; **272:** 14825 – 14829.

24 Grewal JS, Mukhin YV, Garnovskaya MN, Raymond JR, Greene EL. Serotonin 5-HT2A receptor induces TGF-b1 expression in mesangial cells via erk: proliferative and fibrotic signals. *Am J Physiol.* 1999; **276:** 922 – 930.

25 Watts SW, Yang P, Banes AK, Baez M. Activation of erk mitogen activated protein kinase proteins by vascular serotonin receptors. *J Cardiovasc Pharmacol.* 2001; **38:** 539 – 551.

26 Lefebvre H, Cartier D, Duparc C, Lihrmann I, Contesse V, Delarue C, et al. Characterization of serotonin (4) receptors in adrenocortical aldosterone-producing adenomas: *in vivo* and *in vitro* studies. *J Clin Endocrinol Metab.* 2002; **87:** 1211 – 1216.

27 Lambert HW, Lauder JM. Serotonin receptor agonists that increase cyclic AMP positively regulate IGF-I in mouse mandibular mesenchymal cells. *Dev Neurosci.* 1999; **21:** 105 – 112.

28 Dizeyi N, Bjartell A, Hedlund P, Tasken KA, Gadaleanu V, Abrahamsson PA. Expression of serotonin receptor 2B and 4 in human prostate cancer tissue and effects of their antagonists on prostate cancer cell lines. *Eur Urol.* 2005; **47:** 895 – 900.

29 Siddiqui EJ, Shabir M, Mikhailidis DP, Thompson CS, Mumtaz FH. The role of serotonin (5-hydroxytryptamine 1A and 1B) receptors in prostate cancer. *J Urol.* 2006; **176:** 1648 – 1653.