Pravastatin induces cell cycle arrest and decreased production of VEGF and bFGF in multiple myeloma cell line

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Received: June 23, 2014 – Accepted: October 17, 2014 – Distributed: February 29, 2016
(With 4 Figures)

Abstract
Multiple myeloma (MM) is a B cell bone marrow neoplasia characterized by inflammation with an intense secretion of growth factors that promote tumor growth, cell survival, migration and invasion. The aim of this study was to evaluate the effects of pravastatin, a drug used to reduce cholesterol, in a MM cell line. Cell cycle and viability were determinate by Trypan Blue and Propidium Iodide. IL6, VEGF, bFGF and TGFβ were quantified by ELISA and qRT-PCR including here de HMG CoA reductase. It was observed reduction of cell viability, increase of cells in G0/G1 phase of the cell cycle and reducing the factors VEGF and bFGF without influence on 3-Methyl-Glutaryl Coenzyme A reductase expression. The results demonstrated that pravastatin induces cell cycle arrest in G0/G1 and decreased production of growth factors in Multiple Myeloma cell line.

Keywords: pravastatin, Multiple Myeloma, 3-Methyl-Glutaryl Coenzyme A reductase, vascular endothelial growth factor, fibroblast growth factor.

Pravastatina induz parada no ciclo celular e diminuição na produção de VEGF e bFGF em linhagem de Mieloma Múltiplo

Resumo
O Mieloma Múltiplo é uma neoplasia de linfócitos B da medula óssea, caracterizada por inflamação com uma intensa secreção de fatores de crescimento que promovem o aumento do volume do tumor, sobrevivência celular, migração e invasão. O objetivo deste estudo foi avaliar os efeitos da pravastatina, uma droga usada para reduzir o colesterol, em um linhagem de MM. O ciclo celular e viabilidade foram determinados por Trypan Blue e iodeto de propídio. IL6, VEGF, bFGF e TGFβ foram quantificadas por ELISA e qRT-PCR, incluindo aqui de HMG CoA redutase. Observou-se a redução da viabilidade das células, aumento de células na fase G0/G1 do ciclo celular e redução no VEGF e bFGF, sem influência na expressão da enzima 3-Metil-Glutaril Coenzima A redutase. Os resultados demonstraram que a pravastatina induz parada no ciclo celular em G0/G1 e diminuição da produção de fatores de crescimento em várias linhas de células de Mieloma.

Palavras-chave: pravastatina, Mieloma Múltiplo, 3-Metil-Glutarl Coenzima A redutase, vascular endothelial growth factor, fibroblast growth factor.

1. Introduction
Multiple Myeloma (MM) is a neoplastic disease that affects antibodies-secreting B cells fully differentiated, which emerges and expands at the bone marrow (Zhan et al., 2006; Giuliani and Rizzoli, 2007). It is the second most common hematopoietic neoplastic disease (Gadó et al., 2001). The proliferation of tumor cells in bone marrow...
The reduction in synthesis of FPP, farnesylpyrophosphate (FPP) (isopentenyladenine, dolichol, ubiquinone, geranylpyrophosphate (GGPP), geroschol, ubiquinone, and desmosterol), decreases its binding to cellular proteins responsible for intracellular signaling such as Rho, Rac, and Cdc42 (Roy et al., 2011). The binding of TGFβ (transforming growth factor β) to its receptor promotes activation of intracellular mediators, whose effects include immunomodulation, cell cycle, and angiogenesis (Ma and Ma, 2011).

Over the last decade, Statins, the most commercial drug all over the world, prescribed as cholesterol-lowering agents, have revealed other effects, including immunomodulation, neuroprotection, improvement of bone metabolism and antitumour. The inhibition of the enzyme HMG-CoA reductase, an essential key in the biosynthesis of cholesterol (Medina 2010; Musso et al., 2011), demonstrates to be the key point to reduce cholesterol and several compounds like isopentenyladenine, dolichol, ubiquinone, geranylpyrophosphate (FPP), squalene (GGPP), farnesylpyrophosphate (FPP) (Wong et al., 2005; Gauthaman et al., 2009). The reduction in synthesis of isoprenoids (GGPP, FPP), decreases its binding to cellular proteins responsible for intracellular signaling such as Rho, Rac and Cdc42 (Roy et al., 2011; Musso et al., 2011).

The aim of this study was to assess the effects of Pravastatin, a HMG-CoA reductase inhibitor, over a MM cell line, with a focus on cell cycle, inflammatory and growth factors response, cholesterol production and pleiotropic effects.

2. Methods

2.1. Cell culture

RPMI 8226 multiple myeloma cells were grown in RPMI 1640 medium supplemented with 10% fetal bovine serum (FBS), 100 U/mL penicillin/streptomycin and 24 mM NaHCO₃ at 37 °C in a humidified atmosphere containing 5% CO₂. Cells were seeded at an initial density of 4×10⁴ cells/cm² (RPMI 8226). Upon confluence, Pravastatin was added to the media at a concentration of 0.3-0.9 μM for different times.

2.2. Cell viability

Multiple Myeloma cells were plated at a density of 1×10⁶ cells/well. Six-well tissue culture plates (Corning, NY) were used. Cells were treated with Pravastatin for three consecutive days (24h, 48 h, and 72h). Cell proliferation and viability were determined by Trypan Blue exclusion method. Experiments were performed three times in triplicate.

2.3. Analysis of cell cycle by flow cytometry

Cell viability was examined by the trypan blue exclusion method. Cell cycle analysis was performed by flow cytometry. Cells were seeded at a density of 2×10⁶ cells/cm² (RPMI 8226). After 24h cells were treated with 0.3-0.9 μM of pravastatin for up to 72h. At the end of the experiment, cells were trypsinized (0.05% trypsin in 0.02% EDTA) and washed 3 times with PBS, fixed in 70% ethanol, and stained with propidium iodide (PI; 50 μg/mL, final concentration), for 30 min in the dark, according to the method described by Vindelov et al. (1983). All analyses were done using a FACScalibur flow cytometer (Becton Dickinson, San Jose, CA). The red fluorescence of PI was collected through a 585/42-nm band – pass filter, and the fluorescence signals were measured in a linear scale of 1024 channels. For each sample, at least 10000 events were acquired and the data were analyzed using two appropriate software (CELLQuest, Becton Dickinson, San Jose, CA; ModFit LT 2.0). Cells in S/G1/M (proliferating) and G0/G phases, and hypodiploid cells (cells under death process) were analyzed.

2.4. Evaluation of growth factors

IL-6, VEGF, bFGF and TGFβ were investigated after treatment of cells in culture with pravastatin in three different concentrations: 0.3 μM, 0.6 μM and 0.9 μM. The samples of supernatant were withdrawn after 24, 48 and 72 hours after the contact of cells with pravastatin. The supernatant was analyzed by ELISA (Enzyme Linked Immuno Sorbent Assay) to determine the levels of growth factors surveyed. The ELISA plates were read at the Life Lab reader MX range 2001 at 450/690 nm. VEGF and bFGF were quantified by RayBio® kit and IL-6 and TGFβ by eBioscience kit® following the methodology described by the manufacturers.

2.5. RNA extraction and quantitative RT-PCR (qRT-PCR) assays

Total RNA from the MM cultured cells was isolated using the Illustra RNAspin Mini RNA Isolation Kit (GE Healthcare), according to the manufacturer’s instructions. One microgram of total RNA were reverse transcribed using the First-Strand cDNA Synthesis Kit (GE Healthcare), as recommended by manufacturer protocol. Gene expression of HMG CoA, TGF β, VEGF, IL-6 and β FGF was quantified by qRT-PCR in a Stratagene MXPro 3005P thermocycler. The cDNAs were amplified in duplicate PCR reactions using the Brilliant SYBR® Green Master Mix (Agilent), 10 μM of each primer (HMG f: 5′GACCATCTGCATGATGTCCA 3′; HMG r: 5′GGTTTACGGTACCCGCTCTCC 3′; TGF f: 5′GGACCTGAGGCGCAGACTACTA 3′; TGF r: 5′GGTTTACGGTACCCGCTCTCC 3′; VEGF f: 5′CCTCCGAAAATGGACTTGAG 3′; VEGF r: 5′GACAGTCTCGCGTGACGATA 3′; IL6 f: 5′CTCACGCTGAAAGAGGAGA 3′; IL6 r: 5′TGATTTTACCCAGGCAAGTCT 3′; bFGF f: 5′TGCATATCCGACCCGATCT 3′; bFGF r: 5′GGTTTACGGTACCCGCTCTCC 3′).
Pravastatin reduces the number of viable cells. This effect was assessed by Zhong et al., 2011 in the Brazilian Journal of Biology with the use of pravastatin in the studied cells (Figure 1).

Interestingly, the levels of HMGCoA have not changed after 72 hours of incubation, showing that this effect is both, concentration/time dependent. The lower concentration of pravastatin (0.9 μM) promoted cytostatic effect only after 72 hours of incubation, showing that this concentration produced a significant decrease in the number of cells in G0/G1 cell cycle phase after 72 hours. The lower concentration of pravastatin (0.3 μM) was not able to affect cell viability. Interestingly, the concentration of 0.6 μM and 0.9 μM promoted cytostatic effect after 72 hours of incubation, showing that these concentrations are able to reduce VEGF and bFGF levels at supernatant of the cells, meanwhile did not cause changes in the secretion of VEGF and bFGF.

Thereafter, we observe the action of pravastatin in the cell cycle by the methodology of PI. The incubation of the MM cell line with pravastatin (0.6 μM and 0.9 μM) resulted in an increase in the number of cells in G0/G1 cell cycle phase after 72 hours. The lower concentration of pravastatin (0.3 μM) was insufficient to provide cell cycle arrest in a significant quantity of cells. The Figure 2 shows the G0/G1 cell cycle arrest. It’s important to emphasize that these cell lines are known to have different size and shape, and to concentrate the major amount of cells in the G2/M, and to be able to synthesize and secrete IL-6.

The main factors released by the cell line and that are involved in proliferation of MM cell were evaluated. These factors are shown in Figure 3. The three periods, 24h, 48h and 72h were evaluated. For sake of clarity the results shown are for 48h of treatment. Pravastatin reduced VEGF and bFGF levels at supernatant of the cells, meanwhile did not cause changes in the secretion of IL-6 and TGFβ.

To confirm the results obtained with the ELISA we performed a qRT-PCR. In addition to the factors studied we also evaluated the expression of HMGCoA reductase. Pravastatin was able to increase only VEGF mRNA levels. Interestingly, the levels of HMGCoA have not changed with the use of pravastatin in the studied cells (Figure 4).

3. Results

To verify if pravastatin affects cell cycle replication, firstly, we assess the cell viability. We observed a decrease at cells numbers after the addition of pravastatin only at higher concentrations (0.6 μM and 0.9 μM). Pravastatin at 0.3 μM was not able to affect cell viability. Interestingly, the concentration of 0.6 μM and 0.9 μM promoted cytostatic effect after 72 hours of incubation, showing that this effect is both, concentration/time dependent (Figure 1).

Thereafter, we observe the action of pravastatin in the cell cycle by the methodology of PI. The incubation of the MM cell line with pravastatin (0.6 μM and 0.9 μM), result in an increase in the number of cells in G0/G1 cell cycle phase after 72 hours. The lower concentration of pravastatin (0.3 μM) was insufficient to provide cell cycle arrest in a significant quantity of cells. The Figure 2 shows the G0/G1 cell cycle arrest. It’s important to emphasize that these cell lines are known to have different size and shape, and to concentrate the major amount of cells in the G2/M, and to be able to synthesize and secrete IL-6.

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4. Discussion

The literature has reported different effects of statins in neoplastic cells, such as induction of apoptosis, decreased cell proliferation, arrest in G0/G1 cell cycle and reduction of inflammatory cytokines. These effects have been tested in different cancers such as melanoma (Favero et al., 2010), thyroid cancer (Zhong et al., 2011) osteosarcoma (Tsukabi et al., 2011), hepatocellular carcinoma (Tijeras-Raballand et al., 2010). Additionally, several studies have shown that statins reduce cell proliferation in hematopoietic malignancies such as chronic lymphocytic leukemia (Podhorecka et al., 2010), acute promyelocytic leukemia NB4 (Sassano et al., 2007) and MM (Otsuki et al., 2004). Wong et al. (2007) showed that the sensitivity of cells to lovastatin is associated with a specific profile of genetic abnormalities. Another study (Clendening et al., 2010) attributed the sensitivity of cancer cells to statins dysregulation of the mevalonate pathway. After the evaluation of a large panel of MM cell lines Wong et al. (2007) found that 50% of the studied strains are sensitive to lovastatin.

A Japanese study (Otsuki et al., 2003) observed that about a third of the strains tested were MM pravastatin sensitive. Different strains of melanoma showed varied susceptibility to statins, the effects related to cell cycle arrest and apoptosis (Zhong et al., 2011). This effect was observed in other cancers (Xiang et al., 2011) where lovastatin inhibited cell proliferation in ATC strains aggressive thyroid cancer in vitro, raising the level of p27 protein, which inhibits the activity of CDK2 holding the cells in G1 phase.

Other effects attributed to statins refer to modulation of inflammatory mediators and growth factors. Here, we showed that pravastatin reduced VEGF and bFGF levels when compared to control cells. Despite of involvement of
IL-6 at the progression of multiple myeloma, the mRNA and protein levels of this cytokine was not changed by pravastatin treatment. This agrees with a similar result obtained before by other study (Otsuki et al., 2003). Likewise, despite the extensive evidence, showing that TGF-β is a key player in cell proliferation, differentiation and apoptosis, pravastatin effect on MM cells cycle is no explained by changes in this growth factor production. Nevertheless, we cannot rule out the possibility that pravastatin affect the signaling pathway of IL-6 and TGF-β.

The reduction of VEGF and FGF was observed by others (Cho et al., 2008) who note the reduction of VEGF in vitro and in vivo. Several studies shows (Zhong et al., 2011) that statins reduce mRNA of FGF, HGF and TGFβ in osteosarcoma cells in culture. These growth factors are due to inhibition of GGPP (geranyl-geranyl pyrophosphate), preventing the location of Ras to the plasma membrane and subsequent activation of pathways MEK/ERK (extracellular signal controlled by the kinase) and PI3K/AKT (phosphatidylinositol kinase 3 / protein kinase C).

In conclusion, the results of our work showed that Pravastatin induces: cell cycle arrest at G0/G1 allied to a decrease in cell growth and survival in a MM cell line;
Figure 3. Pravastatin induces the loss of VEGF and FGF. Evaluation of different factors in the supernatant culture of MM treated with Pravastatin in different concentrations (ELISA assay). The result shown is representative of 48h of treatment in triplicate. Each bar represents the mean with their standard deviations. Statistical analysis was performed using Student’s t-test. * p < 0.05 compared with the control group.
Figure 4. Pravastatin not change the expression of HMG CoA reductase. Evaluation of different mRNA by qRT PCR. The result shown is representative of 48h of treatment performed three times in triplicate. Threshold cycle (Ct) was measured and a relative change in the expression level of one specific gene was presented as $2^{-\Delta\Delta Ct}$. Each bar represents the mean with their standard deviations. Statistical analysis was performed using Student’s t-test. * p < 0.05 compared with the control group.

decrease in VEGF and bFGF; did not change IL-6 and TGFβ. These effects should be, in part, due to pleiotropic effects and not by the 3-Methyl-GLutaryl Coenzyme A reductase inhibition.

References


