Effect of Propranolol on Angiogenic Factors in Human Hematopoietic Cell Lines in vitro

Fatemeh Hajighasemi*1 and Sakineh Hajighasemi2

1Dept. of Immunology, Faculty of Medicine, Shahed University, Tehran; 2Mostafa Khomeini Hospital, Shahed University, Tehran, Iran

Received 17 March 2009; revised 8 May 2009; accepted 19 August 2009

ABSTRACT

Background: Beta-adrenergic blocking agents have been broadly used for treatment of many cardiovascular diseases such as arterial hypertension and ischemic heart failure. Anti-tumoral, anti-inflammatory and anti-angiogenesis effects of propranolol (a non-selective beta-adrenergic blocker) have been shown. Angiogenesis (replenish of the pre-existing vascular networks) plays a critical role in some pathological conditions such as tumor expansion and metastasis. In this study, we investigated the effects of propranolol on vascular endothelial growth factor (VEGF) production and matrix metalloproteinase-2 (MMP-2) activity (two important angiogenic factors) in human leukemic cell lines in vitro. Methods: Two human leukemic T (Molt-4 and Jurkat) and one monocyte (U937) cell lines were used in this study. The cells were cultured in complete RPMI medium and then incubated with different concentrations of propranolol (0.3-30 µM) in the presence or absence of phorbol myristate acetate (PMA, 25 ng/ml) for 48 hours. The level of VEGF secreted in the cell culture supernatants was measured with enzyme-linked immunosorbent assay kits (R and D systems) and MMP-2 activity in cell-conditioned media was evaluated by gelatin zymography. Results: Propranolol significantly decreased VEGF production and also MMP-2 activity in PMA-activated human leukemic cell lines Molt-4, Jurkat and U937 at 30 µM concentration of the drug compared to untreated control cells (P<0.05). Conclusion: Propranolol might be a useful anti-angiogenic agent in hematopoietic malignancies. Thus, propranolol along with its chronic long-term usage in cardiac problems may have potential implication in treatment of leukemia. Iran. Biomed. J. 13 (4): 223-228, 2009

Keywords: Propranolol, Angiogenesis, Vascular endothelial growth factor (VEGF), Matrix metalloproteinase-2 (MMP-2), Leukemia

INTRODUCTION

Beta-adrenergic blocking agents have been broadly used for treatment of many cardiovascular diseases such as arterial hypertension and ischemic heart failure [1-3] and also non-cardiovascular diseases [4] such as severe migraine attacks [5]. Anti-tumoral and anti-inflammatory effects of beta-blockers have also been reported [6-9]. Furthermore, the inhibitory effects of propranolol (a non-selective beta-adrenergic blocker) on norepinephrine-mediated vascular endothelial growth factor (VEGF) expression in adipose tissue [10] and norepinephrine-stimulated release of functional angiogenic factors in nasopharyngeal carcinoma tumor cells [11] have been described. Angiogenesis (replenish of the pre-existing vascular networks) plays a critical role in some physiological conditions such as wound healing and also in pathological conditions such as tumor expansion and metastasis, rheumatoid arthritis, diabetic retinopathy and peripheral arterial disease [12-14]. Modification of angiogenesis seems to have potential implication in treatment of different diseases such as cancers and ischemic heart failure [15]. Several agents known as angiogenic factors including cytokines such as fibroblast growth factor, (VEGF), hepatocyte growth factor (HGF), placental growth factor and stromal cell-derived factor-1alpha [16, 17], chemokines [18] and matrix metalloproteinases (MMP) [19] are implicated in angiogenesis. VEGF is a very important regulator of angiogenesis [20, 21] and has a crucial role in cancer growth and progression [22]. VEGF blockade has been validated as a therapeutic strategy in adult cancers [23]. Another important angiogenic factors
are MMP, a group of enzymes that play an essential role in degradation of extracellular matrix macromolecules and remodeling of connective tissue matrices which consequently facilitates angiogenesis [19] and have an important role in tumor growth and metastasis [24].

Based on the long-term and wide spread utilization of propranolol in cardiac and also non-cardiac diseases [2, 5] as well as its anti-tumor and anti-inflammatory properties [6-8] and besides its attenuating effect on angiogenic factors level in some carcinoma such as nasopharyngeal cancerous cells [11], we decided to investigate the effects of propranolol on VEGF production and MMP-2 activity (two important angiogenic factors) in three human phorbol myristat acetate (PMA)-stimulated leukemic cell lines in vitro. We used PMA as a potent inducer of VEGF production and MMP-2 activity [25, 26].

**MATERIALS AND METHODS**

*Materials.* RPMI-1640 medium, penicillin, streptomycin, PMA and trypan blue were purchased from Sigma (USA) and FCS from Gibco (USA). VEGF standard ELISA kit was obtained from R and D systems (USA). Propranolol was a kind gift from Hakim Co. Ltd. (Tehran, Iran). Microtiter plates, flasks and tubes were from Nunc (Falcon, USA).

*Cell lines.* Human leukemic T cells [Molt-4 (NCBI C149) and Jurkat (NCBI C121)] and monocyte [U937 (NCBI C130)] were obtained from NCBI (National Cell Bank of Iran, Pasteur Institute of Iran, Tehran). The cells were maintained in RPMI-1640 medium supplemented with 10% FCS in 5% CO\textsubscript{2} at 37°C.

*Preparation of propranolol.* Propranolol was dissolved in RPMI-1640 medium and stored at -20°C until use. Drug was diluted in culture medium to prepare the needed concentrations before use.

*Cell culture and treatment.* The human leukemic cells were cultured in RPMI-1640 medium supplemented with 10% FCS, penicillin (100 IU/ml) and streptomycin (100 µg/ml) in 5% CO\textsubscript{2} at 37°C. The cells were seeded at a density of 2 × 10\textsuperscript{6} cell/ml and then incubated with different concentrations of propranolol (0.3-30 µM) in the presence or absence of PMA (25 ng/ml) for 48 hours. The supernatants of cell culture media were collected and used for VEGF assay and zymography. All experiments were done in triplicate.

**VEGF protein assay.** The amount of VEGF secreted in the cell culture supernatants by human leukemic cell lines was measured with the Quantikine human VEGF ELISA kits (R and D systems) according to the manufacturer’s instructions. This assay uses the quantitative sandwich enzyme immunoassay technique. Complete RPMI medium was used as control and human recombinant VEGF\textsubscript{165} was employed as standard for drawing the standard curves.

**Evaluation of MMP-2 activity by gelatin zymography.** MMP-2 activity in cell-conditioned media was evaluated by gelatin zymography technique according to the modified Kleiner and Stetler-Stevenson method [27]. Briefly, cell culture supernatants were subjected to SDS-PAGE on 10% polyacrylamide gel copolymerized with 2 mg/ml gelatin A in the presence of 0.1% SDS under non-reducing conditions at a constant voltage of 80 V for three hours. After electrophoresis, the gels were washed in 2.5% Triton X-100 for one hour to remove SDS and then incubated in a buffer containing 0.1 M Tris-HCl, pH 7.4 and 10 mM CaCl\textsubscript{2} at 37°C overnight. Afterwards, the gels were stained with 0.5% Coomassie brilliant blue and then destained. Proteolytic activity of enzyme were detected as clear bands of gelatin lysis against a blue background. The relative intensity of lysed bands to the control band was measured by using UVI Pro gel documentation system (Vilber Lourmat, Marne-la-Vallee Cedex 1, France) and expressed as relative gelatinolytic activity.

**Statistical analysis.** Effect of the drug on each cell line was performed in three independent experiments and the results were expressed as mean ± SEM. Statistical comparisons among groups were made by analysis of variance (ANOVA). P<0.05 was considered significant. Test of multiple comparison of Tukey was applied (5%) for statistically significant differences. For statistical analysis and graph making, the software SPSS 11.5 and Excel 2003 were used, respectively.

**RESULTS**

**Propranolol effect on VEGF production in PMA-stimulated human leukemic cell lines.** VEGF production was rather low in unstimulated Molt-4
and Jurkat cells, but PMA (25 ng/ml) significantly increased VEGF production in both leukemic cells after 48 hour of incubation time (Fig. 1A and 1B) \((P<0.05)\). Results depicted in Figure 1C show that U937 cells produced a large amount of VEGF without any stimulation and PMA did not show any significant effect on VEGF production by U937 cells. Propranolol significantly decreased VEGF production in the presence or absence of PMA by Molt-4 cells at 30 \(\mu\)M concentration of the drug after 48 hours incubation time \((P<0.05)\) (Fig. 1A). As illustrated in Figure 1B, propranolol markedly decreased VEGF secretion in the presence or absence of PMA by Jurkat cells at 30 \(\mu\)M dose of the drug after 48 hours incubation time \((P<0.05)\). As can be seen in Figure 1C, propranolol considerably reduced the VEGF production by U937 cells in the presence or absence of PMA at 30 \(\mu\)M dose of the drug after 48 hours incubation time \((P<0.05)\).

**Propranolol effect on PMA-induced MMP-2 activity in human leukemic cell lines.** MMP-2 activity in unstimulated leukemic cell lines used in this study was not detectable but PMA induced MMP-2 activity in Molt-4, Jurkat and U937 cells compared with untreated control cells (Data not shown). As shown in Figure 2, propranolol significantly decreased the PMA-induced MMP-2 activity in all leukemic cells used in this study at 30 \(\mu\)M dose of the drug after 48 hours incubation time \((P<0.05)\).

**DISCUSSION**

In this study, we showed that propranolol (at 30 \(\mu\)M concentration) significantly decreased the VEGF production by human leukemic T (Molt-4 and Jurkat) and monocytic (U937) cells after 48 hours incubation. These findings are consistent with Fredriksson et al. [10] and Yang et al. [11] studies reported that propranolol inhibited the norepinephrine-mediated VEGF expression in adipose tissue and norepinephrine-stimulated release of functional angiogenic factors in nasopharyngeal carcinoma tumor cells. Moreover, anti-tumoral effect of propranolol on a variety of cancers such as pulmonary adenocarcinoma [28], uterine leiomyoma

![Fig. 1. Effect of propranolol on VEGF secretion by human leukemic (A) Molt-4 T-cell (B) Jurkat T-cell and (C) U937 monocytic cell lines. The cells \(2 \times 10^6\) cells/ml were treated with different concentrations of propranolol \(0.3-30 \, \mu\)M for 48 hours in the presence or absence of PMA \(25 \, \text{ng/ml}\). At the end of treatment, VEGF concentration in conditioned medium was measured by ELISA. Data are mean ± SEM of three independent experiments. *\(P<0.05\) was considered significant.](http://IBJ.pasteur.ac.ir)

![Fig. 2. Effect of propranolol on PMA-induced MMP-2 activity in human leukemic Molt-4, Jurkat and U937 cell lines. The leukemic cells \(2 \times 10^6\) cells/ml were treated with different concentrations of propranolol \(0.3-30 \, \mu\)M for 48 hours in the presence of PMA \(25 \, \text{ng/ml}\). At the end of treatment, MMP-2 activity in conditioned medium was measured by gelatin zymography. Data are mean ± SEM of three independent experiments. *\(P<0.05\) was considered significant.](http://IBJ.pasteur.ac.ir)
and 48 hours) [37].

concentration in all incubation times tested (12, 24
expression [32] and serum TNF-
propranolol which decreased the VEGF production
considered that in our study, the concentration of
angiogenesis effects through inhibition of VEGF
heart failure [3] may be in part owing to its anti-
treatment of ischemic heart failure has been reported
results. Potential implication of anti-angiogenesis in
attenuating effect on VEGF production shown in our
inflammatory effects [28-33] together with its
inhibitory effect on VEGF secretion.

In the present study, we also showed that propranolol significantly decreased the PMA-
MMP-2 activity in all leukemic cells used in
this study at 30 µM concentration. These results are
once again consistent with Yang et al. [11] findings
reported the inhibitory effect of propranolol on
norepinephrine-mediated up-regulation of MMP-2
and MMP-9 production in nasopharyngeal
carcinoma. It should be noted that we assessed the
MMP-2 activity by gelatin zymography technique
whereas in Yang et al. [11] study, MMP-2 level was
detected by ELISA and MMP activity was
determined by membrane invasion culture system.
Nevertheless, the similar results were obtained by
different techniques in this study and by Yang et al.
[11]. Since MMP have an important role in
inflammation and tumor growth [24], it seems that
inhibitory effects of propranolol on MMP-2 activity
may be the other cause for its anti-tumoral and anti-
inflammatory effects [28-33] together with its
attenuating effect on VEGF production shown in our
results. Potential implication of anti-angiogenesis in
treatment of ischemic heart failure has been reported
[15]. So, positive effect of propranolol on ischemic
heart failure [3] may be in part owing to its anti-
angiogenesis effects through inhibition of VEGF
production and MMP-2 activity. It should be
considered that in our study, the concentration of
propranolol which decreased the VEGF production
and MMP-2 activity in vitro was higher than that of
usually used in cardiovascular patients. Our previous
study showed that propranolol had a significant
cytotoxic effect against the same leukemic cells used
in the present study at ≥ 0.2 mM (200 µM)
concentration in all incubation times tested (12, 24
and 48 hours) [37].

Accordingly, propranolol had not any cytotoxic
effect on the cell lines examined in this study, at the
mentioned concentrations (0.3-30 µM) and incubation time (48 hours). Hence, decrease of
VEGF production or MMP-2 activity in the present
study is not due to cytotoxic effect of propranolol.

To best of our knowledge, this is the first report
about inhibitory effect of propranolol on VEGF
production and MMP-2 activity in human leukemic

cell lines. Taken together, our data showed that the
anti-tumoral and anti-inflammatory effects of
propranolol reported by other investigators [6-9]
seems to be related in part to its inhibitory effect on
angiogenesis through suppression of VEGF
production and MMP-2 activity, as VEGF and
MMP-2 are important mediators of angiogenesis
[19, 21]. At the other hand, the important role of
angiogenesis in leukemic patients has been reported
[20, 22]. Therefore, anti-angiogenic compounds may
be positive agents in treatment of leukemia. Our
results suggest that propranolol with inhibitory
effect on VEGF production and MMP-2 activity
might be a useful anti-angiogenic mediator in
hematopoietic cancers. Accordingly, propranolol
may have potential implication in treatment of
leukemia along with its chronic long-term usage in
cardiac diseases. Further investigations about
propranolol effect on angiogenic factors in
peripheral blood mononuclear cells as well as
hematopoietic malignancies in vivo are also
warranted.

REFERENCES


2. Priviero, F.B., Teixeira C.E., Claudino, M.A., De
Vascular effects of long-term propranolol
administration after chronic nitric oxide blockade.

3. Igarashi, N., Nozawa, T., Fuji, N., Suzuki, T.,
Matsuki, A., Nakadate, T., Igawa, A. and Inoue, H.
(2006) Influence of beta-adrenoceptor blockade on
the myocardial accumulation of fatty acid tracer and
its intracellular metabolism in the heart after
ischemia-reperfusion injury. Circ. J. 70 (11): 1509-
1514.

50-year historical perspective. Am. J. Ther. 15 (6):
565-576.

migraine. Disch. Med. Wochenschr. 132 (41): 2153-
2158.

http://IBJ.pasteur.ac.ir


http://IBJ.pasteur.ac.ir


http://IBJ.pasteur.ac.ir