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ORIGINAL PAPER

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The vitamin D analogue BXL-628 inhibits growth factor-stimulated proliferation and invasion of DU145 prostate cancer cells

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Abstract *Purpose:* Suppression of the invasive phenotype is essential in developing new therapeutic tools to treat advanced prostate cancer (PC) indicating that androgen-independent prostate cancer (AI-PC) is characterized by increased metastatic potential. In the present study, we have investigated the effect of the nonhypercalcemic vitamin D analogue BXL-628 on proliferation and invasive properties of the human PC cell line DU145. In particular, the effect of the analogue was tested following stimulation with a potent growth factor, keratinocyte growth factor (KGF), which stimulates both proliferation and invasion of these cells. We have also evaluated the effect of the analogue on KGF stimulation of PI3K/AKT signaling pathway. *Methods:* Cell proliferation was determined by cell counting. Invasion through Matrigel was evaluated using Boyden chambers. PI3K activity was measured by immunokinase assay and AKT phosphorylation was evaluated by western blot analysis. Keratinocyte growth factor receptor (KGFR) autotransphosphorylation was evaluated by western blot after immunoprecipitation of the receptor. *Results:* BXL-628 is able to inhibit both proliferation and invasion of DU145 cells in basal conditions and in response to KGF. Following stimulation with KGF, the inhibition is due to suppression of KGFR autotransphosphorylation and downstream PI3K/AKT activation, both achieved following a brief (5 min) incubation with the analogue. This effect on KGFR autophosphorylation was still present when cells were treated with the α-amanitin, an inhibitor of RNA transcription, indicating a rapid, nongenomic effect. *Conclusions:* Our results demonstrate that the vitamin D analogue BXL-628 is able to suppress KGF-induced proliferation and invasion of AI-PC cells in vitro, prospecting a possible use of the drug, which is currently in phase II clinical studies for benign prostatic hyperplasia, in the treatment of advanced prostate cancer.

Keywords BXL-628 · Keratinocyte growth factor · Invasion · Proliferation

Abbrevations AI-PC: Androgen-independent prostate cancer · KGF: Keratinocyte growth factor · KGFR: Keratinocyte growth factor receptor · PI3K: Phosphatidylinositol 3 kinase · VDR: Vitamin D receptor

Introduction

Prostate Cancer (PC) is one of the most common cancer and the second leading cause of death in American men (Gronberg 2003). In the advanced stages of the disease androgen ablation therapy represents a valuable tool for the treatment of these patients. However, in almost all patients androgen-independent (AI) clones of tumor cells develop after a year of treatment and at this stage no other efficacious therapies are available. The mechanisms responsible for transition to androgen independence are still unclear (So et al. 2005), however, a striking characteristics of androgen-independent prostate cancer (AI-PC) is related to its higher invasive potential compared to androgen-dependent stages (Chung et al. 2005). In vitro studies using available androgen-sensitive human PC cell line and androgen-insensitive human PC cell line indicate that, at least in part, higher

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invasiveness of AI-PC may be due to loss of regulation of genes involved in invasion (Baldi et al. 2003). Bone metastases have been reported to occur in 85–100% of patients with advanced PC. Thus, novel therapies to increase the chance and the quality of life in patients with advanced PC should aim at inhibition, besides proliferation, also the invasive ability of the tumors.

Based on their anti-proliferative, pro-apoptotic and pro-differentiative properties, vitamin D analogues have been extensively studied as possible treatments for cancer (Nagpal et al. 2005).

Several studies have focused on the role of calcitriol and its receptor, the vitamin D receptor (VDR), in PC (Peehl and Feldman 2004) and clinical trials have shown the capacity of calcitriol to inhibit prostate specific antigen (PSA) increase in PC patients (Trump et al. 2004). Polymorphisms in the VDR gene have been implicated as risk factors for PC development and progression (Habuchi et al. 2000) and the growth inhibitory effects of calcitriol and its analogues have been well characterized in PC cells (Nagpal et al. 2005). However, much less is known about the effect of these compounds on the invasive ability of PC cells, although calcitriol has been shown to reduce invasion in PC cells (Sung and Feldman 2000; Schwartz et al. 1997).

A major problem with the clinical use of calcitriol is its hypercalcemia-inducing capacity, prompting the search for less hypercalcemic analogues. The less hypercalcemic Vitamin D analogue BXL-353 shows a strong antiproliferative activity in PC cell lines and benign stromal cell in vitro, being effective at very low concentrations (Crescioli et al. 2000, 2002). This compound inhibits in vitro growth of both benign prostate hyperplasia (BPH) and PC cells by disrupting KGF-induced growth, decreasing bcl-2 over-expression and inducing apoptosis (Crescioli et al. 2002, 2003). Strikingly, the effect of the compound on KGF-induced growth is mediated by inhibition of KGF-induced KGF receptor autotransphosphorylation following a brief (5 min) treatment (Crescioli et al. 2002), indicating the involvement of a rapid, nongenomic mechanism of the vitamin D analogue on growth inhibition in PC.

In the present study, we have investigated the effect of a recently developed vitamin D analogue, BXL-628, on KGF-induced invasion and proliferation of the androgen-independent PC cell line DU145. Previous data from our laboratory demonstrated the capacity of this analogue to decrease prostate cell proliferation both in vitro, using primary cultures of human BPH cells and in vivo, showing inhibition of prostate growth in intact and castrated, testosterone-replaced, rats (Crescioli et al. 2004). Based on these data, BXL-628 is currently being tested in phase II trials for the treatment of benign prostate hyperplasia. Results in the present study examine the effects of BXL-628 on KGF-induced autotransphosphorylation of its receptor, and downstream activation of the PI3K/AKT pathway, in AI-PC cells.

Materials and methods

Materials

Analogue 1-*a*-fluoro-25-hydroxy-16,23*E*-diene-26,27-bishomo-20-epi-cholecalciferol (BXL-628) was provided by BioXell (Milan, Italy). Anti-KGFR polyclonal antibody was purchased from Santa Cruz Biotechnology, Inc. (Santa Cruz, CA, USA). Antiphosphotyrosine PY20 antibody and [γ-^{32}P]ATP were obtained from ICN (Costa Mesa, CA, USA). Keratinocyte growth factor (KGF) was obtained from Prepro Tech EC (London, England). LY294002 was from Calbiochem (California, USA). Phosphoinositides were from AVANTI POLAR-Lipids, Inc. (Alabaster, AL, USA). Protein A and Protein G-Sepharose were obtained from Amersham Pharmacia Biotech Italia (Cologno Monzese, Italy). Matrigel was from Becton Dickinson (Franklin Lakes, NJ, USA). Protein measurement Coomassie kit was purchased from Bio-Rad Laboratories, Inc. (Hercules, CA, USA). Annexin-V-Fluos staining kit was obtained from Roche Molecular Biochemicals (Milan, Italy). DMEM, antibiotics, and other not specified reagents were purchased from SIGMA Chemical Co. (St. Louis, MO, USA).

Cell culture

Androgen independent human cell lines, DU145 and PC3, were obtained from American Tissue Culture Collection (Bethesda, Maryland, USA) and maintained, respectively, in DMEM and HAM-F12 Coon supplemented with 10% FBS, penicillin (100 UI/ml), streptomycin (10 mg/ml), and glutamine (2 mM).

Cell proliferation assay

All proliferation tests were performed after 24 h of cell starvation in phenol red- and serum-free medium containing 0.1% BSA. After starvation, cells were incubated in the same medium as before, with or without specific stimuli. Thereafter, cells were trypsinized, and each experimental point was derived from counting in the hemocytometer and then averaging at least six different fields for each well as previously reported (Crescioli et al. 2003). Experiments were performed seeding 4×10^4 cells onto 12-well plates in growth medium and incubated for 48 h with (1) increasing concentrations of BXL-628 (1×10^{-12}, 1×10^{-11}, 1×10^{-10}, 1×10^{-9}, 1×10^{-8} M) with or without fixed concentration of KGF (10 ng/ml) or fixed concentration of bFGF (10 ng/ml); (2) fixed concentration of LY 294002 (10 nM) with or without KGF (10 ng/ml). In the same experiment each experimental point was repeated in triplicate and experiments were performed at least three times. Cell growth results are

expressed as the percentage of growth compared with their relative controls.

Invasion assay

Invasion assays were performed as described previously (Bonaccorsi et al. 2000, 2004a, b) according to Albini et al. (1987) using the Boyden chambers equipped with 8 μm porosity polyvinylpyrrolidone-free polycarbonate filters (VWR International, Milan, Italy). A thin layer of Matrigel solution (50 μg/ml) was overlaid on the upper surface of the filter and allowed to gel by incubating the filters at 37°C for 30 min. Cell ability to invade the substrate was assessed by using some different stimuli: KGF (10 ng/ml), in presence or in absence of the inhibitor, BXL-628 (1×10^{-8} M). These molecules were added to the bottom well of the Boyden chambers. Cells (9.5×10^{4}) were then added to the top of the chambers and incubated for 24 h at 37°C. Migrated cells were quantitated by counting cells with a Zeiss microscope (Oberkochen, Germany) equipped with brightfield optics (40× magnification). Results are expressed as the percentage of number of migrated cells per high-power field with respect to control.

Immunoprecipitation and Western blot analysis

Protein extraction and immunoprecipitation were performed as previously described (Bonaccorsi et al. 1997). Briefly, cells were scraped in PBS supplemented with 1 mM Na_3VO_4, centrifuged and resuspended in lysis buffer [20 mM Tris, pH 7.4, 150 mM NaCl, 0.25% NP-40, 1 mM Na_3VO_4, 1 mM phenylmethyl-sulfonyl fluoride (PMSF)]. After protein measurement (Coomassie kit), aliquots of cell lysates containing equal amount of proteins (500 μg) were incubated for 1 h with 30 μl of Protein A (or Protein G)-Sepharose for preclearing. Precleared lysates were then incubated for 1 h using 5 μg of specific anti-KGFR antibodies on ice followed by overnight incubation at 4°C with 30 μl of Protein A (or Protein G)-Sepharose. The immunobeads were washed three times in lysis buffer and then resuspended in 10 μl of 2× Laemmli's reducing sample buffer (62.5 mM Tris pH 6.8, 10% glycerol, 2% SDS, 2.5% pyronin, and 200 mM dithiothreitol), boiled at 95°C for 5 min and loaded onto 8% polyacrylamide–bisacrylamide gels. After SDS-PAGE, proteins were transferred to nitrocellulose membrane (Sigma Co., St. Louis, MO, USA) and incubated with the specific primary antibodies for 2 h in 1% BM blocking (Roche, Milan, Italy) in TTBS solution (Tris-buffered saline containing 0.1% Tween 20, pH 7.4), washed and incubated with peroxidase-conjugated relative secondary antibodies (1:4,000) for 2 h. After washing, the blots were incubated with enhanced chemiluminescence (BM, Roche, Milan, Italy) detection reagent and exposed to film. After the first blotting, nitrocellulose membranes were stripped at 50°C for 30 min in stripping buffer (100 mM 2β-mercaptoethanol, 2% sodium dodecyl sulphate, 62.5 mM Tris–HCl pH 6.7) and re-probed with specific primary antibodies to detect different proteins.

Annexin-V binding assay

Annexin-V binding assay was used to detect translocation of membrane phosphatidylserine (PS) from the inner to the outer side of the plasma membrane, since the exposure of PS is considered an early sign of apoptosis (Kagan et al. 2000). The assay was performed by using the "Annexin-V-Fluos staining Kit" (Roche). Before treatment, cells (1×10^{6}) were kept in serum-free medium for at least 24 h, then cells were incubated for 8 h in the presence or absence of BXL-628 (1×10^{-8} M), then cells (1×10^{6}) were washed, tripsinized, centrifuged. After two washes in PBS, cells were resuspended in 100 μl of incubation buffer (supplied by manufacturer), 2 μl of Annexin-V-Fluos labeling reagent (Ann-V-F, Annexin-V conjugated to fluorescein, supplied at the 200× concentration by Roche), and 2 μl of propidium iodide solution (PI, 30 μg/ml in PBS) were added. After incubation (15 min in the dark at room temperature) samples were analyzed by flow cytometry. For each experimental set, two cell suspensions were prepared for instrumental setting and data analysis: (1) by omitting both Ann-V-F and PI staining (nonspecific fluorescence sample), and (2) by omitting only the PI staining (sample for compensation, see below). Ann-V-F green fluorescence and PI red fluorescence were revealed by using FL-1 and FL-2 detectors, respectively. Fluorescence compensation was set by acquiring sperm labeled with only Ann-V-F. For each sample 10,000 events were recorded at a flow rate of 200/300 cells/s. Debris was gated out by establishing a region around the population of interest, in the Forward Scatter/Side Scatter (FSC/SSC) dot plot. Quadrant setting was established in the FL-1/FL-2 dot plot corresponding to the autofluorescence sample by including more than 99% of total events in the lower left quadrant.

PI3K assay

PI3K activity was evaluated in vitro assay as previously described (Luconi et al. 2004). Briefly, cells were stimulated with KGF (5 min) in the presence or absence of BXL-628, scraped in PBS supplemented with 1 mM Na_3VO_4, centrifuged and extracted with lysis buffer (20 mM Tris, pH 7.4, 137 mM NaCl, 1 mM $CaCl_2$, 1 mM $MgCl_2$, 1% NP-40, 1 mM Na_3VO_4, 1 mM PMSF). After measurement of proteins, the aliquots of cell extracts containing equivalent amount of proteins (500 μg) were incubated for 1 h with 50 μl of Protein G-Sepharose for preclearing. Precleared lysates were then incubated with an antiphosphotyrosine PY20 antibody overnight at 4°C with 50 μl of Protein G-Sepharose as described above. The Sepharose beads were washed two

times with lysis buffer and twice with a 10 mM Tris–HCl (pH 7.4) containing 0.1 mM EGTA and 5 mM LiCl. After removal from the last wash, the beads were suspended in kinase buffer (10 mM Tris–HCl, 150 mM NaCl, 5 mM EDTA) containing 20 μg of L-α-phosphatidylinositol, 25 mM $MgCl_2$, and 10 μCi of [γ-^{32}P]ATP, and incubated for 20 min at room temperature. The reaction was stopped by the addition of 60 μl of HCl 6 M and 160 μl of a mixture of chloroform and methanol (1:1). Lipids were then resolved by thin layer chromatography plates, TLC silica gel 60 (Merck Laborchimica, Florence, Italy), in chloroform, methanol, water, and ammonium hydroxide (60:47:11.3:2). Dried TLC sheets were developed by autoradiography. Quantifications of the bands were performed using a Kodak image analysis system.

Statistical analysis

All the data are shown as mean ± SEM of the indicated number of experiments. Statistical analysis was performed with ANOVA and Student's *t* test for unpaired and, when applicable, for paired data. IC50 for dose–response curves was calculated using the program ALLFIT.

Results

Inhibitory effects of BXL-628 on basal and KGF-mediated proliferation of DU145 cells

As shown in the inset of Fig. 1, treatment with the vitamin D analogue BXL-628 inhibits dose dependently DU145 cell proliferation with an IC50 of 22.1 ± 19.1 pM. Similar results are obtained when cell proliferation was assessed using the MTT assay (results not shown). As shown in Fig. 1, KGF stimulates DU145 cell proliferation at the concentration of 10 ng/ml. Treatment with BXL-628 completely and dose dependently inhibits proliferation stimulated by the growth factor (Fig. 1). Similar effects were also observed in the AI cell line PC3 [percentage number of cells: 100 ± 17 control, 121.3 ± 13 KGF (10 ng/ml), 69.9 ± 9.9 KGF + BXL-628 (1×10^{-8} M)], although, in line with previous work by our group (Crescioli et al. 2002), responsiveness of PC3 cells to KGF was lower with respect to DU145. To evaluate whether the inhibitory effects of BXL-628 were specific

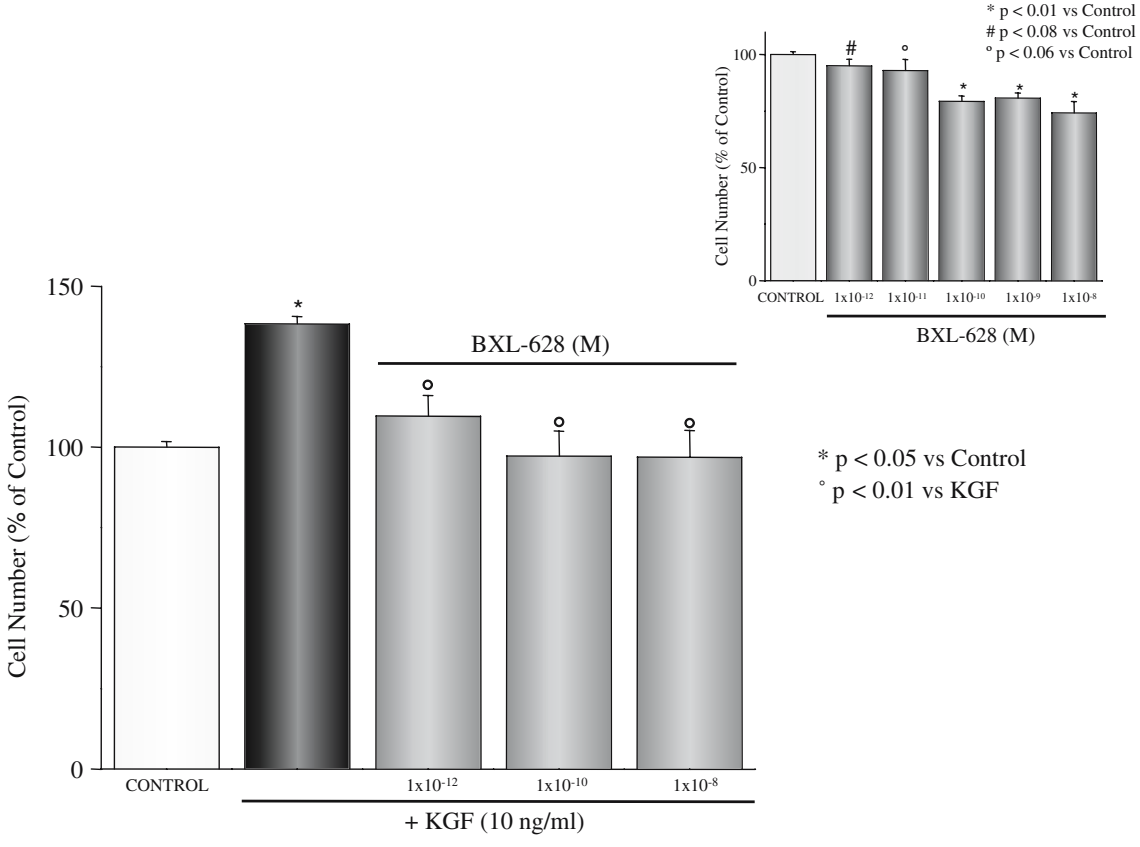

Fig. 1 Effect of BXL-628 on basal (*inset*) and KGF-stimulated proliferation of DU145 cells, determined by cell counting. Cells were treated for 48 h with increased concentrations of the analogue with or without fixed concentrations of KGF (10 ng/ml). Each experimental point was determined in triplicate and experiments were performed at least three times. Results are expressed as the percentage of growth compared with their relative controls

for KGF, we tested its effect on bFGF-stimulated proliferation of DU145 cells. Our results demonstrated an inhibitory effect of BXL-628 also on bFGF-mediated proliferation [percentage number of cells: 100 ± 8.6 control, 138 ± 19.5 bFGF (10 ng/ml), 74.1 ± 9.2 bFGF + BXL-628 (1×10^{-8} M)].

Previous studies from our group (Crescioli et al. 2000, 2002) indicate that vitamin D analogues exert in part their antiproliferative effects by inducing cell apoptosis. To evaluate whether the inhibitory effect of BXL-628 on DU145 proliferation was due to induction of apoptosis, we evaluated phosphatidylserine exposure (an early sign of cell apoptosis, for review see Kagan et al. 2000) in live cells by Annexin-V binding after 8-h incubation in the presence of the analogue (1×10^{-8} M). We found that BXL-628 induces a significant increase of Annexin-V binding to the cells (percentage Annexin-V positive live cells: 57 ± 1.7 control, 62 ± 1.2 BXL-628, $n = 6$, $P = 0.017$).

Effect of BXL-628 on KGF-induced Matrigel invasion of DU145 cells

Next, we investigated the effect of BXL-628 on KGF-stimulated Matrigel invasion. Previous studies investigating the effects of vitamin D analogues on cancer cell invasion and migration utilized long-term treatment protocols with at least 48 h cell preincubation before performing the invasion assay (Yudoh et al. 1999; Koli and Keski-Oja 2000; Schwartz et al. 1997). The inhibitory effect of KGF-induced KGFR autotransphosphorylation obtained after short-term (5 min) exposure to BXL-353 in BPH and PC cells (Crescioli et al. 2002) prompted us to evaluate the effect of BXL-628 on in vitro invasiveness of DU145 cells avoiding preincubation of the cells with the analogue, which was added directly to the bottom of Boyden chambers. As shown in Fig. 2 (panel a), the stimulatory effect of KGF on DU145 cell invasion is completely inhibited by the vitamin D analogue at the

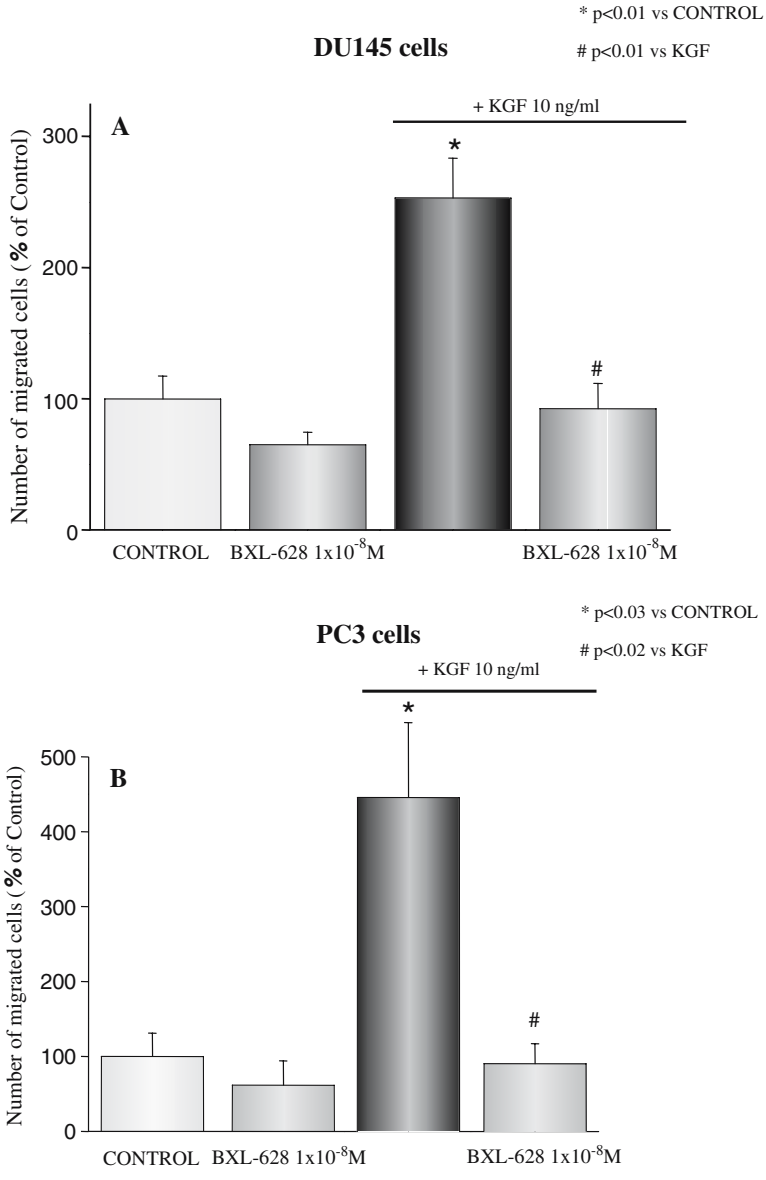

Fig. 2 Effect of BXL-628 (1×10^{-8} M) on Matrigel invasion of DU145 cells (panel **a**) and PC3 cells (panel **b**) in basal conditions and following stimulation with KGF (10 ng/ml). Matrigel invasion was evaluated by using Boyden chambers. Number of cells migrated was evaluated in at least ten fields for each experimental point and averaged. Data are mean ± SEM of the percentage of cell migrated with respect to control of four different experiments

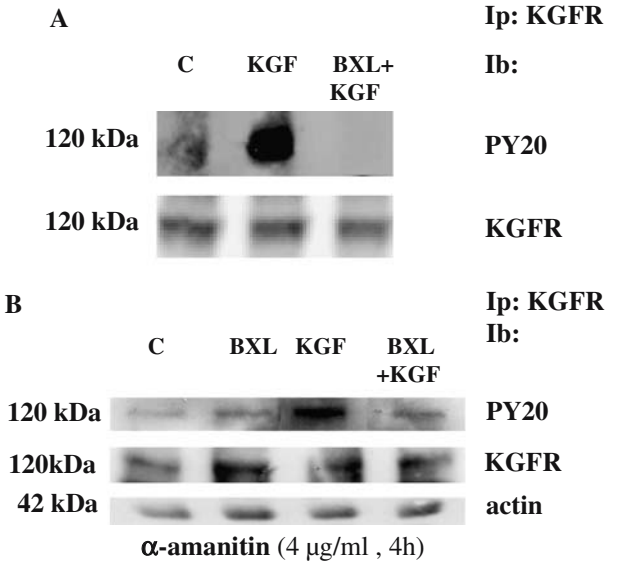

Fig. 3 Effect of BXL-628 (1×10^{-8} M) on KGF (10 ng/ml)-induced autotransphosphorylation of its receptor. Cells were pre-treated (panel **b**) or not (panel **a**) for 4 h with α-amanitin (4 μg/ml, 4 h). After stimulations, cell lysates were immunoprecipitated using anti-KGFR antibody, run onto SDS-PAGE and analyzed first for expression of phosphorylation using anti-phosphotyrosine (PY20) antibody (*upper blots*) and, after stripping and re-probing, for receptor expression using anti-KGFR and, for the experiment with α-amanitin, for actin expression. Representative of two similar experiments

concentration of 1×10^{-8} M. Similar results were observed in the PC3 cell line (Fig. 2, panel b).

Effects of BXL-628 on KGF-induced signaling pathways

Next, we sought to investigate the effects of the compound on KGF-induced signaling in DU145 cells. In particular, we evaluated the effect of the analogue on KGFR autotransphosphorylation and on the downstream signaling pathway PI3K/AKT. Cells were pre-treated for a short time (5 min) with BXL-628 before addition of KGF. For autotransphosphorylation studies, KGF receptor was immunoprecipitated using specific antibody. As shown in Fig. 3a, BXL-628 abrogated KGF-induced autotransphosphorylation of its receptor. Interestingly, this effect was obtained following a brief (5 min) preincubation with the analogue, suggesting a rapid, nongenomic effect. To further investigate this possibility, we used the RNA transcription inhibitor α-amanitin. As shown in Fig. 3b, the inhibitory effect of BXL-628 was still present when the experiment was conducted following 4-h incubation with 4 μg/ml α-amanitin, strongly indicating absence of transcriptional regulation in the inhibitory effect of BXL-628 on KGFR autophosphorylation.

In view of the key role exerted by the PI3K/AKT signaling pathway on invasion and migration of PC3 cells (Bonaccorsi et al. 2004a) as well as on KGF-mediated proliferation of DU145 cells (Fig. 4) where the inhibitory effect of the PI3K inhibitor LY294002 on KGF-induced proliferation of DU145 cells is shown, we evaluated the effect of BXL-628 on KGF-induced PI3K activation. As shown in Fig. 5, BXL-628 inhibits the stimulatory effect of KGF on PI3K activity. Next, we evaluated the effect of the compound on the main downstream PI3K effector, the serine/threonine kinase AKT (Wymann and Pirola 1998). AKT is activated by serine/threonine phosphorylation following PI3K activation and this phosphorylation is essential for its activity. When AKT is activated, it regulates a variety of cellular functions including cell survival, cell growth, cell differentiation, cell cycle progression, and cell metabolism (Paez and Sellers 2003). Thus, we evaluated serine phosphorylation of AKT by Western blot analysis, employing a specific anti-serine phosphorylated AKT antibody, following DU145 cell stimulation with KGF

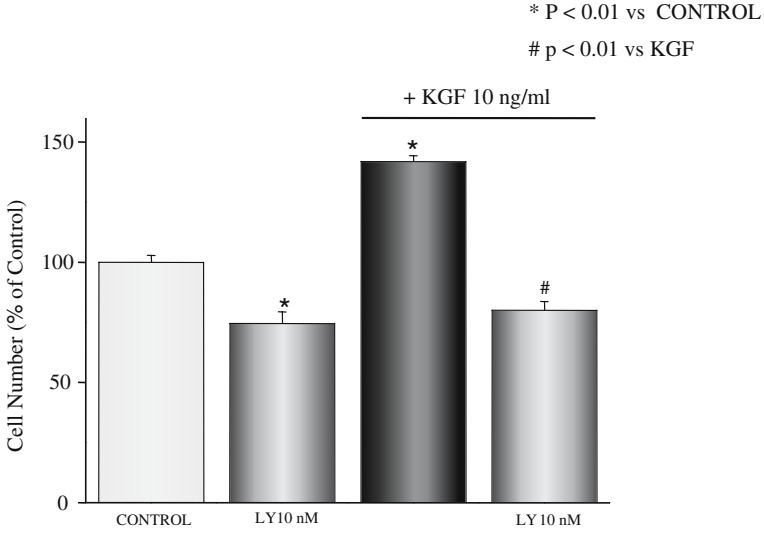

Fig. 4 Effect of the phosphatidylinositol-3 kinase inhibitor, LY294002, on proliferation of DU145 cells, determined by cell counting. Cells were treated for 48 h with fixed concentration of LY294002 (10 nM) with or without KGF (10 ng/ml). Each experimental point was determined in triplicate and experiments were performed at least three times. Results are expressed as the percentage of growth compared with their relative controls

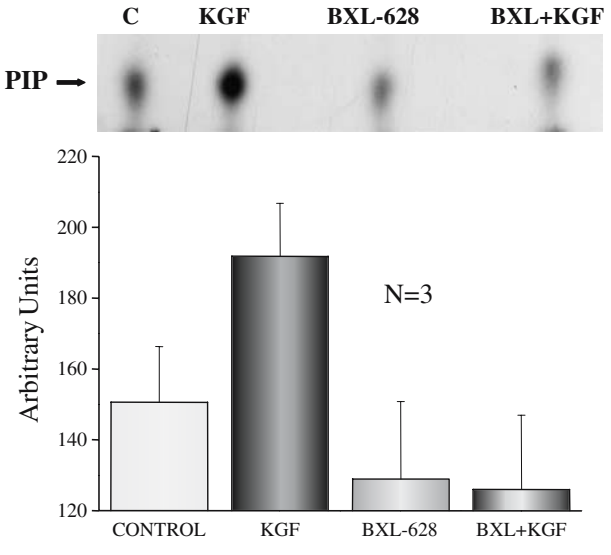

Fig. 5 Effect of BXL-628 (1×10^{-8} M) on KGF (10 ng/ml)-mediated PI3K activation. After stimulation, cell lysates were immunoprecipitated using an anti-phosphotyrosine (PY20) antibody, followed by immunokinase assay in the presence of [γ-^{32}P]ATP (for details, see Materials and methods). Products of the reaction are evaluated by thin-layer chromatography followed by autoradiography. *Upper panels* show representative experiments, where *spots* correspond to the PI3-kinase catalytic product [^{32}P]phosphatidylinositol phosphate (PIP), while *lower panels* show mean ± SEM quantification (arbitrary units) of the band for the indicated number of experiments

in the presence or absence of BXL-628. BXL-628 inhibits KGF-stimulated AKT serine phosphorylation (Fig. 6) in agreement with the results on receptor autotransphosphorylation (Fig. 3) and PI3K activity (Fig. 5).

Discussion

Prostrate cancer in advanced stages is a fatal disease because of failure of androgen deprivation therapy and lack of alternative effective therapy. An ideal therapeutic agent for AI-PC should target both proliferation as well as invasive and metastatic properties of the tumor cells, since once progressed to androgen independence, PC is characterized also by higher invasive ability (Chung et al. 2005). The present study demonstrates, for the first time, that the vitamin D analogue BXL-628 is able to

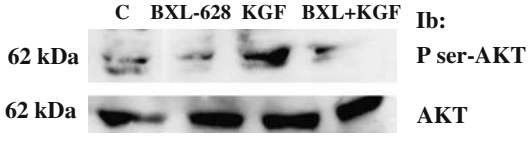

Fig. 6 Effect of BXL-628 (1×10^{-8} M) on KGF (10 ng/ml)-mediated phosphorylation of the PI3K downstream effector AKT. After stimulation, equal amount of total cell lysates was subjected to SDS-PAGE, transferred to nitrocellulose membranes, and blotted with anti-phosphoserine AKT antibodies (*upper panels*) followed by stripping and re-probing with anti-AKT antibodies (*lower panels*). Representative of two similar experiments

reduce both proliferation and invasive ability of the AI-PC cell lines, DU145 and PC3, in basal conditions and in response to a main growth factor, namely KGF, implicated in proliferation, progression, and invasion of PC (Russell et al. 1998). At least in part, the antiproliferative effect of BXL-628 is due to induction of apoptosis, as demonstrated by increased surface exposure of PS in live cells after treatment with the analogue. This result is in line with previous data from our group showing induction of apoptosis by vitamin D analogues in several cell types (Crescioli et al. 2000, 2002, 2003, 2004).

Keratinocyte growth factor (KGF) is a physiological paracrine factor for prostate epithelial cells produced by stromal cells under the control of androgen (Planz et al. 1999a), but in the case of PC the paracrine loop is mostly replaced by an autocrine one (Planz et al. 1999b) with enhanced effectiveness on cell proliferation. Thus, the growth factor and its receptor represent an important target for therapeutic strategies in advanced PC. Several receptor tyrosine kinase (RTK) inhibitors have been developed in recent years to specifically block RTKs such as EGFR, VGFR, and FGFR (Noble et al. 2004). Among these, Gefitinib, an inhibitor of EGFR tyrosine kinase, has been shown to effectively block, in vitro, EGFR signaling and EGF-mediated proliferation and invasion of PC cell lines (Vicentini et al. 2003; Bonaccorsi et al. 2004b). However, despite clear effectiveness in other solid tumors (Blay et al. 2005), results of a phase II clinical trial for PC with this inhibitor were disappointing (Canil et al. 2005). Lack of effectiveness of Gefitinib has been demonstrated also for renal and bladder cancers (Drucker et al. 2003; Petrylak et al. 2003) although abnormal EGFR expression/signaling has been demonstrated in these malignancies, suggesting tissue selectivity for these agents. It is likely that combination with other therapies is required for the treatment of these malignancies. Here, we show that BXL-628, consistent with previous results obtained with vitamin D analogue BXL-353 (Crescioli et al. 2002), is able to inhibit, as RTK inhibitors, KGFR autotransphosphorylation in DU145 cells through a rapid, likely nongenomic, mechanism of action. Although further studies are needed to define the molecular mechanism underlying KGFR tyrosine phosphorylation inhibition, the demonstration that the downstream PI3K/AKT pathway is also inhibited, suggests that BXL-628 is effective in blocking KGF action. As mentioned above, BXL-628 is less hypercalcemic compared to calcitriol and other analogues. In addition, BXL-628 is currently being tested in phase II clinical trials for the treatment of BPH and preliminary results indicate significant reduction of prostate volume compared to placebo adverse effects (Montorsi F, presentation at the EUA, Istanbul, March 2005), strongly indicating that the prostate is a target for this drug.

In conclusion, our results show that the nonhypercalcemic vitamin D analogue, BXL-628, is able to block proliferation and invasion in response to KGF in the AI cell line DU145. Together with several evidence in the

literature pointing out a differentiating role of calcitriol and its analogues in carcinoma cells (Stewart and Weigel 2004), our data provide a rationale for the development of novel analogues to be employed in the treatment of AI or advanced PC. As previously suggested (Beer et al. 2005) these analogues may be used in combination with other antineoplastic agents (such as RTK inhibitors) to induce additive or synergistic effects by simultaneously targeting multiple components of the same pathway or several targets at the same time. On the other hand, targeting multiple signaling pathways appears to be the most practicable way in approaching prostate cancer (McCarty 2004).

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