XIAP Regulates Akt Activity and Caspase-3-dependent Cleavage during Cisplatin-induced Apoptosis in Human Ovarian Epithelial Cancer Cells

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ABSTRACT

Chemoresistance is a major hurdle for successful cancer therapy. Although multiple mechanisms have been implicated in being involved in cisplatin resistance, recent evidence has suggested that X-linked inhibitor of apoptosis protein (XIAP) may be a key determinant in chemoresistance in ovarian cancer. Cell fate is determined by a balance between cell survival and apoptotic signaling. Whereas phosphatidylinositol 3-kinase (PI 3-K) and XIAP are believed to be important cell survival factors in human ovarian surface epithelial cancer cells, if and how they interact to confer resistance to chemotherapy is not known. In the present study, we have investigated the role of XIAP in the regulation of the PI 3-K/Akt survival pathway in chemosensitive (A2780-s, OV2008, and OVCA3-3) and resistant (A2780-cp) ovarian cancer cell lines and the nature of this interaction in cell death/survival signaling. Cisplatin decreased XIAP protein levels and induced Akt cleavage and apoptosis in chemosensitive, but not in resistant, ovarian cancer cells. Cisplatin also induced cleavage of caspase-9 and caspase-3, a process blocked by XIAP overexpression. Pretreatment of ovarian cancer cells and their whole cell lysate with tetrapeptide inhibitors of caspases in vitro significantly decreased Akt cleavage induced by cisplatin and exogenous active caspase-3. Adenoviral sense XIAP cDNA expression increased XIAP protein levels and increased Akt phosphorylation, indicative of activation of Akt and, likely, of PI 3-K. This was associated with a decrease in cisplatin-induced apoptosis. In a cell line (OVCA3-3) where basal phosphorylated Akt levels were high, XIAP overexpression failed to increase further the level of this phosphoprotein. XIAP down-regulation induced Akt cleavage and apoptosis, and treatment of whole cell lysate with recombinant active caspase-3 resulted in a similar pattern of Akt cleavage. In the presence of the PI 3-K inhibitor (LY294002), XIAP overexpression failed to block cisplatin-induced apoptosis and to induce Akt phosphorylation, suggesting that the site of action of XIAP is upstream of Akt in this cell survival pathway. Taken together, the results indicate that XIAP prevents apoptosis through a PI 3-K-dependent inhibition of the caspase cascade. These results demonstrate a novel mechanism by which XIAP regulates apoptosis and the possible involvement of the PI 3-K/Akt survival pathway in XIAP-mediated chemoresistance of ovarian cancer cells.

INTRODUCTION

Akt is a serine/threonine protein kinase originally discovered as the cellular counterpart of the v-Akt transforming protein of a retrovirus (AKT8) that caused T-cell lymphomas in mice (1). It is also known as protein kinase B or Rac (2–4). Akt is an inactive cytosolic protein; it is recruited to the plasma membrane and activated by phosphorylation at threonine 308 and serine 473 in response to growth factors or cytokines (5–9). The cell survival role of Akt has been demonstrated in multiple cell lineages (10–14).

The molecule responsible for the recruitment of Akt to the cellular membrane as well as activation of Akt is the lipid kinase PI 3-K. PI 3-K phosphorylates phosphoinositides (PtdIns) at position 3 of the inositol ring. More recently, PI 3-K has emerged as an important signaling molecule for diverse growth factor receptors in a variety of cell types (15). Upon activation, PI 3-K induces Akt phosphorylation, which in turn phosphorylates and blocks the actions of Bad, a pro-apoptotic member of the Bcl-2 family (16), as well as altering the activity of a number of other pro-apoptotic mediators, including caspase-9, forkhead, and NFkB (10, 17, 18). The kinase Akt has been shown to induce phosphorylation of pro-caspase-9, suggesting that caspase-processing and apoptosis can be directly regulated by protein phosphorylation (17). This is supported by the observation that an activated form of Akt is also able to block apoptosis (13). The recent identification of a new oncogene derived from the regulatory subunit of PI 3-K (p65-PI 3 K) linked PI 3-K to mammalian tumor development (19). Increased PI 3-K has also been proposed to induce oncogenic transformation (19–21). More recently, another study revealed that PIK3CA gene (encoding the p110α subunit of PI 3-K) is a putative oncogene in ovarian cancer (22); this is supported by a similar observation in cervical cancer (23).

IAPs constitute a family of intracellular anti-apoptotic proteins that were first identified as analogues of genes present in baculoviruses. It includes XIAP, HIAP-1, human HIAP-2, neuronal apoptosis inhibitory protein, and survivin (24, 25). These proteins are characterized by the presence of a caspase recruitment domain and an NH2-terminal baculovirus inhibitor of apoptosis repeat motif. With the exception of XIAP and survivin, they also include a COOH-terminal ring-zinc finger domain, believed to be involved in protein-protein and protein-nucleic acid interactions. Only a few reports to date have addressed the mechanisms of action of these anti-apoptotic proteins. XIAP has been shown to be a direct inhibitor of caspase-3 and caspase-7 (26) and to interfere with the Bax/cytochrome c pathway by inhibiting caspase-9 (27, 28). Overexpression of XIAP has been shown to protect Chinese Hamster Ovary and RARE-1 cells from menadione or growth factor withdrawal-mediated apoptosis (25), to suppress apoptosis in HeLa cells induced by transient transfection with interleukin 1β converting enzyme (29), and to suppress apoptosis induced by the Sindbis virus (30). These reports suggest that XIAP may play a key role in the regulation of apoptosis in cancer cells.

In the present study, we have used ovarian cancer cell lines as an in vitro model to study the role of the PI 3-K/Akt pathway in the anti-apoptotic action of XIAP and to examine its possible involvement in chemoresistance in human ovarian cancer.

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2 The abbreviations used are: PI 3-K, phosphatidylinositol 3-kinase; PtdIns, phosphoinositides; PtdIns(3,4,5)P3, phosphatidylinositol (3,4,5) trisphosphate; IAP, inhibitor of apoptosis protein; XIAP, X-linked IAP; HIAP, human IAP; DMEM:F12, DMEM/Ham’s F-12; PBS, fetal bovine serum; Z-VAD-fmk, benzyl-oxycarbonyl-Val-Ala-Asp-fluoromethyl ketone; DEVD-fmk, benzyl-oxycarbonyl-Asp-Glu-Val-Asp-fluoromethyl ketone; MOI, multiplicities of infection; RT-PCR, reverse transcription-PCR; ILK, integrin-linked kinase.
MATERIALS AND METHODS

Reagents. Cisplatin, Hoechst 33242, and LY294002 were obtained from Sigma (St. Louis, MO). Cisplatin solutions were prepared in the dark and used fresh each time. RPMI 1640, DMEM-F-12, and FBS were purchased from Life Technologies, Inc. (Burlington, Ontario, Canada). Human recombinant active caspase-3 and -9 were purchased from Pharmingen Canada (Mississauga, Ontario, Canada). Polyclonal antihuman p85 PI 3-K antibody was a generous gift from Dr. John Liu (Ontario Cancer Institute, Ottawa, Canada). Anti-human phosphoPlus Akt (Ser473) and Akt antibodies were obtained from Cell Signaling Technology (Burlington, Ontario, Canada). Human recombinant active caspase-3 (10 μg) for 2, 4, and 6 h in the absence or presence of DEVD (25 μM). Akt cleavage analysis was performed by Western blotting.

Cell Culture. Human ovarian surface epithelial cancer cells were gifts from Dr. Rakesh Goel from the Ottawa Regional Cancer Centre, Ottawa, Canada. Cells were cultured in 150-mm bottles at 37°C in an atmosphere of 5% CO₂ in either RPMI 1640 (OVCAR-3) or DMEM-F12 (A2780s and A2780-cp), containing 10% FBS, 1% nonessential amino acids, 0.5% streptomycin-penicillin, and 0.25% fungizone. Cells (1 × 10⁶) were plated in log growth phase onto 60-mm dishes for 24 h in the above culture medium before the initiation of treatment.

Experimental Design. For cisplatin concentration-response studies, culture medium containing 10% FBS was replaced with FBS-free medium, and cells were cultured for 24 h in the presence of different concentrations of cisplatin (0, 1, 5, and 10 μM in DMF). For XIAP sense or antisense adenoviral infections using different MOI, culture medium containing 10% FBS was replaced with 0.5 ml of 10% FBS-medium containing adenoXIVAR anti-sense or anti-sense cDNA, and the cells were incubated initially for 2 h with (coincubation to ensure maximal infection) and then cultured in 2 ml of FBS-free medium for 24 h (antisense XIAP) or 48 h (sense XIAP). After 48 h of sense-XIAP infection, the medium was discarded, and cells were treated for 24 h in the absence or presence of cisplatin (10 μM) and/or 20 μM LY294002 (a specific PI 3-K inhibitor; Ref. 31). At the end of the culture period, floating [recovered by centrifugation (4000 × g for 5 min) and attached [subsequently to trypsin treatment (0.05% trypsin and 0.53 mM EDTA at 37°C for 3–5 min)] cells were pooled and centrifuged (4000 × g for 5 min). For Hoechst staining, cell pellets were resuspended and fixed in 10% formalin (Fisher Scientific, Nepean, Ontario, Canada) containing Hoechst 33242 nuclear stain (12.5 μg/ml) and stored at 4°C for 24 h before being spotted onto slides for fluorescence microscopy. Total protein was extracted from cell pellets with a lysis buffer (pH 7.4) containing 150 mM NaCl, 0.1% SDS, 0.5% sodium deoxycholate, 1% NP40 in PBS, protease inhibitor phenylmethylsulfonyl fluoride (1 mM), and 1 mM sodium orthovanadate. Total RNA was extracted for mRNA measurements using Trizol (Life Technologies, Inc.) according to the manufacturer’s instructions.

Hoechst Staining. Nuclear staining was viewed and photographed using a Zeiss fluorescence microscope. Cells with typical apoptotic nuclear morphology (nuclear shrinkage, condensation, and fragmentation) were identified and counted using randomly selected fields on numbered photographic slides, with the “counter” unaware of the treatment, so as to avoid experimental bias. A minimum of 200 cells/treatment group were counted in each experiment.

Protein Extraction and Western Analysis. Cells were sonicated (10 s) in the lysis buffer, and sonicates were centrifuged (12,000 × g for 20 min at 4°C) to remove insoluble material. The supernatant was recovered and stored at −20°C pending analysis. Protein content was determined with the Bio-Rad DC protein assay. Protein extracts (50 μg) were heated (94°C for 3 min), resolved by 10% SDS-PAGE and electrophoresed to nitrocellulose membranes (15 V for 30 min) using a semidry transfer (Bio-Rad, Mississauga, Ontario, Canada). The membranes were then blocked (2 h, room temperature) with 5% milk powder, then incubated with anti-PI 3-K (1:8000), XIAP (1:2000), Akt (1:1000), or Phospho-PKB/Akt (1:1000) antibody (2 h, room temperature), and subsequently with horseradish peroxidase-conjugated antirabbit secondary antibody (1:5000; room temperature; for 45 min). Peroxidase activity was visualized with the enhanced chemiluminescence kit (Amersham, Arlington Heights, IL) according to the manufacturer’s instructions.

Fig. 1. Effect of cisplatin concentrations on XIAP, PI 3-K, and Akt protein content of human ovarian cancer cell lines. Cells (1 × 10⁶) were plated for 24 h in DMEM-F12–10% FBS and cultured for 24 h in serum-free DMEM-F12 with different cisplatin concentrations (0, 1, 5, and 10 μM). The same amount of vehicle (DMF) was added in each group. Cells were collected for Hoechst staining to count apoptotic cells. Total proteins and RNA were extracted for analysis by Western blot (A) and RT-PCR (B), respectively. Representative blots are presented. Data represent the mean ± SE of four independent experiments.

Fig. 2. Akt cleavage during cisplatin treatment is caspase-3 dependent. A. A2780-s and A2780-cp cells were treated as in Fig. 1B. A2780-s cell lysate was treated in vitro with human recombinant caspase-3 (10 μg) for 2, 4, and 6 h in the absence or presence of DEVD (25 μM). Akt cleavage was assessed by Western analysis.

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protein expression. Representative blots are presented. Data represent the mean ± SE of four independent experiments.
Semiquantitative RT-PCR Analysis. To measure the abundance of PI-3-K (p85), Akt, and XIAP mRNA, primers were chosen as described below and tested with different primer concentrations and different cycles to avoid mRNA amplification near plateau and saturation. Conditions for final analysis were chosen when amplification of mRNA was in the middle of the exponential amplification phase for all cisplatin concentrations tested. Total RNA (400 ng) from each treatment group was used for the preparation of first-strand cDNA by reverse transcription. The RNA samples were incubated (65°C for 10 min) with 0.5 μg oligo(dT)15 primers in a final volume of 10 μl. Samples were then incubated (37°C for 60 min) in 20 μl of a reaction buffer (1X) containing DTT (10 mM), deoxynucleotide triphosphate (1.25 mM), and Mu-108-108-108-loney murine leukemia virus reverse transcriptase (200 units). The reaction volume was brought up to 60 μl with autoclaved water. A negative control was also included, using the same reaction mixture but without Mu-108-108-loney murine leukemia virus reverse transcriptase to ensure the absence of any contaminating genomic DNA in the RNA template.

Expression of the p85 regulatory subunit of the PI-3-K gene was determined by amplification of a 595-bp region of the human p85 PI-3-K cDNA sequence (1819–2413 bp; Ref. 32). Amplification was carried out using the antisense downstream sequence 5′-AAGTTGAACGAGTGGTTG-GG-3′ and the sense upstream sequence 5′-CTGGTGGTACATCATACAGCC-3′. Human Akt1 mRNA (58–1681 bp; Ref. 1) was amplified using sense primer 5′-GCCCT-GGGTCAAGAAGTCA-3′ and antisense primer 5′-CATCCCTCCAAGC-TATGC-3′. For XIAP, the expression of the gene was determined by amplification of a 389-bp region of the XIAP cDNA sequence (973–1361 bp; Ref. 25), and the sequences of the primers were 5′-GAAGACCTCTGGGAACA-3′ (sense) and 5′-CGCC TTAGCTGCTCTTCAGT-3′ (antisense). Each reaction mixture (final volume: 50 μl) contained 1× buffer, reverse transcriptase template, or negative control (5 μl), MgCl2 (1.5 mM), deoxynucleotide triphosphate (0.2 mM), primers (10 μM each), and Taq polymerase (1.5 units). The PCR cycling conditions (30 cycles) chosen were as follows: (a) 30 s at 94°C; (b) 1 min at 55°C; and (c) 1 min at 72°C; with a subsequent 10-min extension at 72°C. Reaction products were analyzed on 1.0% agarose gels. Bands were visualized by ethidium bromide staining.

In Vitro Caspase Inhibition. To assess the role of caspases in cisplatin-induced Akt cleavage, cells were preincubated for 2 h with Z-VAD-fmk (50 μM) or DEVD-fmk (25 μM) in serum-free medium and subsequently cultured for 24 h in the absence or presence of cisplatin (10 μM).

RESULTS

Cisplatin Decreases XIAP Protein Content and Induces Akt Cleavage in Cisplatin-sensitive Ovarian Cancer Cells. To test whether XIAP and PI-3-K/Akt pathway is involved in the action of cisplatin, ovarian cancer cells were cultured with different concentrations of cisplatin for 24 h (Fig. 1). Cisplatin significantly induced apoptosis in a concentration-dependent manner (P < 0.05) in sensitive cells (A2780-s) and had no effect on the resistant variant (A2780-cp). Cisplatin reduced XIAP protein content and induced Akt cleavage, but had no effect on the levels of p85 regulatory subunit of PI-3-K (Fig. 1A). To determine whether the action of cisplatin was mediated through changes in gene expression, RT-PCR analysis was carried out (Fig. 1B). Cisplatin had no effect on the levels of mRNA transcripts of XIAP, PI-3-K (p85), or Akt.

Akt Cleavage Is Mediated through Caspase-3 Activation. Cleavage of caspase-3 and -9 was also observed in response to increasing concentrations of cisplatin in the cisplatin-sensitive cells (A2780-s; Fig. 2). To demonstrate the relationship between the cleavage of Akt and caspase-3 activation, A2780-s cell lysate was incubated for up to 6 h with human recombinant active caspase-3 or -9 in the absence or presence of caspase-inhibitor DEVD (25 μM). Total volume of the reaction was 40 μl. The incubation was terminated with the addition of an equal volume of 2× sample buffer [Tris-HCl (100 mM; pH 6.8), DTT (200 mM), SDS (4% w/v), glycerol (20%; v/v), and bromophenol blue (0.2%)]. Akt cleavage was assessed by Western blotting.

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absence or presence of the specific caspase-3 inhibitor (DEVD, 25 μM; Fig. 2B). The results demonstrate that active caspase-3 was able to cleave Akt in vitro, and this effect could be blocked by the caspase inhibitor. To demonstrate further the importance of caspase activation during cisplatin-induced apoptosis, A2780-s cells were cultured in vitro and treated with cisplatin (10 μM) in the presence or absence of DEVD-fmk or Z-VAD-fmk, two-cell permeable caspase-3 inhibitors (Fig. 3). Addition of these inhibitors to the cell cultures attenuated the decrease in XIAP protein content and the cleavage of procaspase-3 and Akt as well as apoptosis (P < 0.05) induced by cisplatin (Fig. 3).

**XIAP Overexpression Induces Akt Phosphorylation.** To characterize the relationship between XIAP and the PI 3-K/Akt pathway, we overexpressed XIAP protein in three different ovarian cancer cell lines using an adenoviral sense XIAP cDNA (Fig. 4). Overexpression of XIAP increased phospho-Akt contents in A2780-s and OVCAR-3 cells. However, basal phospho-Akt levels were high in OVCAR-3 cells and were not increased further with XIAP expression.

**XIAP Overexpression Blocks Cisplatin-induced Apoptosis.** XIAP overexpression induced Akt phosphorylation in cisplatin-sensitive (A2780-s) and resistant (A2780-cp) ovarian cancer cells (Fig. 5). Overexpression of XIAP blocked cisplatin-induced apoptosis in A2780-s cells, whereas PI 3-K p85 protein levels remained constant. To determine whether the XIAP-induced resistance of the cells to cisplatin might, in part, be attributable to an increased PI 3-K/Akt activity, we tested the effect of cisplatin in the presence of a PI 3-K inhibitor, LY294002 (Fig. 6A). In the presence of XIAP, LY294002 was sufficient to induce a small increase of apoptosis. The combination of LY294002 plus cisplatin induced a synergistic increase in
apoptosis in XIAP-overexpressing A2780-s cells. This increase in cell death was associated with a marked decrease in phospho-Akt levels. In the presence of LY294002 and cisplatin, phospho-Akt levels were also reduced in A2780-cp cells, but this was not sufficient to induce cell death. As shown in Fig. 7, XIAP overexpression also blocked cisplatin-induced procaspase-9 cleavage, an effect which was reversed in the presence of LY294002.

**XIAP Down-Regulation Induces Akt Cleavage and Apoptosis.** Expression of an adenoviral XIAP antisense cDNA in ovarian cancer cells (A2780-s) decreased XIAP content and induced apoptosis in an adenoviral concentration-dependent manner (Fig. 8). XIAP down-regulation also induced procaspase-9 and -3 cleavage as well as Akt cleavage.

**DISCUSSION**

Ovarian epithelial cancer is the fifth leading cause of death among female cancers in America (33). Although chemotherapeutic agents, such as cisplatin, are widely used for the treatment of ovarian cancer, chemoresistance remains a major therapeutic problem, and the molecular mechanisms leading to chemoresistance are poorly understood. In the present study, we have demonstrated that cisplatin can induce apoptosis in a dose-dependent manner in sensitive (A2780-s), but not in resistant (A2780-cp), cell lines. The increased apoptosis was accompanied by a decrease in XIAP protein content but not in mRNA levels, suggesting that cisplatin regulates this anti-apoptotic factor at the protein level rather than by regulation of its gene expression. Although precisely how cisplatin decreases XIAP content in human ovarian cancer cells is not known, it has been shown to increase Fas and Fas ligand expression (34) and to activate downstream caspases.2 Because XIAP is a substrate of caspase-3 and -7 (27), it is possible that the observed decrease in XIAP content could be a consequence of caspase-mediated processing after Fas activation. Alternatively, it is possible that the decrease in XIAP content subsequent to cisplatin challenge may be a consequence of proteasome-mediated processing, involving initially ubiquitination and subsequently degradation of the IAP molecule. In this context, it has recently been demonstrated that XIAP and HIAP-2 in thymocytes exposed to glucocorticoid or etoposide are selectively lost in a proteasome-dependent manner before death and that this process involves the autoubiquitination and degradation of the IAPs (35).

Although the physiological role of XIAP is not fully understood, it is considered an important intracellular anti-apoptotic factor and is known to suppress cell death by binding to and inhibiting caspase-3, -7 (26), and -9 (27). In this regard, a decrease of XIAP levels could induce the apoptotic process, at least in part through activation of caspases. These aspartate-specific proteases cleave and inactivate a number of cellular substrates during the induction of apoptosis (36). They constitute a point of no return in the activation of apoptotic processes (28), and the relative abundance of XIAP may be a key element in cell-fate determination. The mechanism(s) involved in the pro-apoptotic action of caspase-3 in ovarian cancer cells is not clear. It has been suggested that proteins involved in DNA breakdown (37), signal transduction (38, 39), and cytoskeletal proteins (40) may be putative physiological substrates for caspase-3. The action of caspase-3 involves the disruption of survival signals and/or proteins participating in the maintenance of cellular integrity. The present studies demonstrated that the survival factor Akt is cleaved during cisplatin-induced apoptosis and confirmed that this process is caspase-3-mediated. Overexpression of XIAP not only prevented cisplatin-induced Akt cleavage but increased phospho-Akt content. Akt is a protein kinase that promotes cell survival by inhibiting apoptosis, although precisely how it exerts its anti-apoptotic effects is not clear. It has recently been reported to directly phosphorylate and inactivate procaspase-9 as well as to block caspase-9-mediated apoptosis induced by cytochrome c via Apaf-1 in response to an early apoptotic stimuli (Ref. 17; reviewed in Ref. 41). Akt can phosphorylate BAD, resulting in the release of BCL2 and inhibition of the apoptotic process. In addition, Akt can also promote cell survival by phosphorylating and inhibiting a forkhead transcription factor known to regulate Fas ligand gene expression (10).

To investigate the possible role of XIAP in the regulation of PI 3-K in ovarian cancer cells, we examined the influence of adenoviral sense XIAP cDNA expression on phospho-Akt content in the cisplatin sensitive cells A2780-s. XIAP overexpression increased phospho-Akt levels and suppressed cisplatin-induced apoptosis with no effect on the levels of the p85 subunit of PI 3-K, suggesting that XIAP may inhibit apoptosis in part through the activation, but not the expression/degradation, of PI 3-K. This notion was supported by the observation that inhibition of cisplatin-induced apoptosis with XIAP overexpression was reversed in the presence of LY294002, a PI 3-K inhibitor. The inhibition of PI 3-K activity, as evident by a decrease in phospho-Akt content, was sufficient to override the protective effect of XIAP on cisplatin-induced apoptosis. Although LY294002 also decreased phospho-Akt content in the XIAP-overexpressed, cisplatin-treated resistant variant A2780-cp, the levels of phospho-Akt were considerably higher than that in the sensitive cells under identical conditions, and apoptosis was not observed. The present studies have also shown that LY294002 alone induced only a slight decrease in phospho-Akt content as well as a small but nonsignificant increase in apoptosis.

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2 D. Schneiderman, C. W. Xiao, and B. K. Tsang, unpublished data.
Because the cells were treated with LY294002 for 24 h, and the latter has a relatively short half-life, it is possible that the decreased AKT phosphorylation could have been transient (i.e., several hours after treatment). Taken together, these results suggest that the maintenance of a minimal level of phospho-Akt may be required for chemoresistance, and that the ability of XIAP to promote cell survival may in part be attributable to its ability to preserve the integrity and function of PI 3-K/Akt pathway by modulating the cellular content of phospho-Akt. Alternatively in the A2780-cp line, cisplatin resistance maybe mediated through a PI 3-K independent mechanism.

The cellular mechanism(s) by which XIAP increases phospho-Akt content in ovarian cancer cells is not known. An increase in phospho-Akt content may be a consequence of changes in activities of upstream kinases and/or phosphatases. Activation of Akt by PI 3-K requires both PtdIns(3,4,5) P3 (the product of PI 3-K) as well as Akt phosphorylation on threonine-308 and serine-473 residues. The binding of PtdIns(3,4,5) P3 to the pleckstrin homology domain of Akt results in its recruitment to the plasma membrane and exposure of its threonine-308 residue. phosphoinositide-dependent kinase has been shown to be responsible for the threonine-308 phosphorylation of Akt (42), although this phosphorylation alone is not sufficient for full Akt activation, which requires PtdIns(3,4,5) P3-dependent serine-473 phosphorylation. Recently, it has been shown that ILK, a serine and threonine protein kinase, may directly phosphorylate Akt on Ser-473 in vitro (43). However, the present observations that the PI 3-K inhibitor LY294002 was able to suppress the XIAP-induced phospho-Akt content and to increase apoptosis suggest that the site(s) of regulation by XIAP may either be at PI 3-K or at a step(s) upstream. In this context, because the above-mentioned cellular processes are regulated by the activities of protein tyrosine phosphatases, the possibility exists that XIAP may down-regulate phosphatases known to decrease PI 3-K activity. PTEN, a tumor-suppressor gene of a phospholipid phosphatase, is mutated at a high frequency in a wide variety of human gynecological cancers (reviewed in Ref. 44). PTEN is known to decrease PI 3-K activity by directly associating with its p85 subunit. XIAP may down-regulate phosphatases known to phosphorylate and activates protein kinase B. This finding may account for the failure of XIAP to increase phospho-Akt content in this cell line, a characteristic not shared by the A2780 and OV2008 cells. Our present results support the importance of PI 3-K/Akt survival pathway in determining the fate of ovarian cancer cells.

In conclusion, our data suggest that the anti-apoptotic action of XIAP may be mediated in part through its interaction with the PI 3-K pathway. A balance in the expression and actions of cell death and survival factors is critical in cell fate determination (survival versus apoptosis). Although the activity of the PI 3-K/Akt survival pathway may be an important contributor to cancer cell chemosensitivity, other pathways (e.g., Fas/FasL) may also be involved (34). The failure of cisplatin to down-regulate XIAP and PI 3-K expression and to induce apoptosis in cisplatin-resistant cells suggests that these survival pathways may be etiologically relevant to chemoresistance. Additional studies are necessary to determine the precise molecular mechanism by which XIAP regulates the PI 3-K/Akt survival pathway.

REFERENCES


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