**Angiogenesis, Metastasis, and the Cellular Microenvironment**

**IL-6 Promotes Head and Neck Tumor Metastasis by Inducing Epithelial–Mesenchymal Transition via the JAK-STAT3-SNAIL Signaling Pathway**

Arti Yadav¹, Bhavna Kumar¹,², Jharna Datta¹, Theodoros N. Teknos¹,², and Pawan Kumar¹,²

**Abstract**

Epithelial–mesenchymal transition (EMT) is a key process in tumor metastatic cascade that is characterized by the loss of cell–cell junctions and cell polarity, resulting in the acquisition of migratory and invasive properties. However, the precise molecular events that initiate this complex EMT process in head and neck cancers are poorly understood. Increasing evidence suggests that tumor microenvironment plays an important role in promoting EMT in tumor cells. We have previously shown that head and neck tumors exhibit significantly higher Bcl-2 expression in tumor-associated endothelial cells and overexpression of Bcl-2 alone in tumor-associated endothelial cells was sufficient to enhance tumor metastasis of oral squamous cell carcinoma in a severe combined immunodeficient (SCID) mouse model. In this study, we show that endothelial cells expressing Bcl-2 (EC-Bcl-2), when cocultured with head and neck tumor cells (CAL27), significantly enhance EMT-related changes in tumor cells predominantly by the secretion of IL-6. Treatment with recombinant IL-6 or stable IL-6 overexpression in CAL27 cells or immortalized oral epithelial cells (IOE) significantly induced the expression of mesenchymal marker, vimentin, while repressing E-cadherin expression via the JAK/STAT3/Snail signaling pathway. These EMT-related changes were further associated with enhanced tumor and IOE cell scattering and motility. STAT3 knockdown significantly reversed IL-6–mediated tumor and IOE cell motility by inhibiting FAK activation. Furthermore, tumor cells overexpressing IL-6 showed marked increase in lymph node and lung metastasis in a SCID mouse xenograft model. Taken together, these results show a novel function for IL-6 in mediating EMT in head and neck tumor cells and increasing their metastatic potential. *Mol Cancer Res; 9(12); 1658–67. ©2011 AACR.*

**Introduction**

Tumor metastases in head and neck cancer patients almost invariably heralds a poor prognosis with an average survival of 6 months and treatment of the patients is usually palliative (1). Five-year survival rates for patients with early stage localized head and neck cancers are more than 80% but drop to 40% when the disease has spread to the neck nodes, and to below 20% for patients with distant metastatic disease (2). Uncontrolled cell proliferation and angiogenesis are key characteristics of initiation and early growth of epithelial origin cancers (3). However, it is the subsequent acquisition of motility and invasiveness that leads to the metastatic dissemination of these tumor cells (4). Tumor metastasis is a complex process consisting of multiple individual steps (5). A key process in this metastatic cascade that converts an adherent epithelial cell into a migratory cell, which can invade through the extracellular matrix, is known as epithelial–mesenchymal transition (EMT; ref. 6). Many *in vitro* and *in vivo* studies have shown that tumor cells of epithelial origin can acquire mesenchymal phenotype (7, 8) and that these cells are typically seen at the invasive front of primary tumors (4, 9, 10). The role of EMT in tumor metastasis is further highlighted by the observations that acquisition of mesenchymal markers such as vimentin or S100A4 by epithelial cells is associated with increased metastatic potential (11, 12).

Functional loss of E-cadherin in epithelial cell has been considered a hallmark of EMT (13). During tumor progression, E-cadherin can be functionally inactivated or silenced by a number of different mechanisms including somatic mutations (14), downregulation of gene expression through promoter hypermethylation (15), histone deacetylation (16), or transcriptional repression (17). Several EMT-inducing regulators repress E-cadherin transcription via interaction with specific E-boxes of the proximal E-cadherin promoter (7). Most prominent E-cadherin regulators are the snail-related zinc-finger transcription factors (snail and slug;...
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reversed IL-6 and Ala-Eddin Al Moustafa (McGill University, Montreal, epithelial cells (IOE) were provided by Drs. William Foulkes and colleagues recently have reported that Snail is an independent marker of tumor metastasis in patients with HNSCC (23).

A number of studies have highlighted the role of tumor microenvironment in promoting tumor metastasis (24–26). We have recently shown that tumor-associated endothelial cells exhibit significantly higher Bcl-2 expression which directly correlates with metastatic status of head and neck cancer patients (25, 27). In addition, overexpression of Bcl-2 alone in tumor-associated endothelial cells was sufficient to promote tumor metastasis in a severe combined immunodeficient (SCID) mouse model (25). We designed this study to understand how these tumor-associated endothelial cells may be promoting EMT in head and neck tumor cells. Our results suggest that endothelial cells expressing Bcl-2 induce EMT-related changes in tumor cells predominantly via the secretion of IL-6. IL-6 is a pleiotropic cytokine that is involved in acute phase of inflammation and is a major inducer of C-reactive protein (28). Recently, Lederle and colleagues showed that IL-6 promotes malignant growth of skin squamous cell carcinoma by regulating a complex cytokine and protease network (29). IL-6 is one of main chemokines present in serum samples of head and neck cancer patients (25, 27). In addition, overexpression of Bcl-2 directly correlates with metastatic status of head and neck cancer patients and elevated IL-6 levels independently predict tumor recurrence, poor survival, and tumor metastasis (30, 31). However, very little is known about the role of IL-6 in head and neck tumor metastasis and the process of EMT. In this study, we show that treatment of head neck tumor cells or immortalized oral epithelial cells with recombinant IL-6 or stable IL-6 overexpression significantly induced the expression of vimentin and snail proteins while repressing E-cadherin expression. In addition, overexpression of IL-6 in tumor and normal oral epithelial cells significantly enhanced cell scattering and motility. STAT3 knockdown significantly reversed IL-6–mediated EMT phenotype of tumor and immortalized oral epithelial cells. Furthermore, tumor cells overexpressing IL-6, when implanted in SCID mice, showed marked increase in EMT and metastasis to lymph node and lungs. These results suggest an important role of IL-6 in mediating EMT and metastasis of HNSCC tumor cells.

Materials and Methods

Cell culture and reagents

Primary human dermal microvascular endothelial cells were purchased from Lonza. ECs were maintained in endothelial cell basal medium-2 (EBM-2) containing 5% FBS and growth supplements. Head and neck squamous carcinoma cell line CAL27 (ATCC) was maintained in Dulbecco’s modified Eagle’s medium (DMEM) supplemented with 10% FBS. Immortalized (HPV E6/E7) oral epithelial cells (IOE) were provided by Drs. William Foulkes and Ala-Eddin Al Moustafa (McGill University, Montreal, Quebec, Canada; ref. 32) and cultured in keratinocyte serum-free medium (K-SFM, Invitrogen). Primary antibodies against E-Cadherin (Catalog no. 3195), Akt (Catalog no. 9272), pAkt (Catalog no. 9271), STAT3 (Catalog no. 9132), STAT3 (pY705; Catalog no. 9131), STAT3 (pS727; Catalog no. 9134), p44/42 MAPK (ERK1/2, Catalog no. 9102), pERK1/2 (Catalog no. 4377), FAK (Catalog no. 3285) and Tubulin (Catalog no. 2148) were purchased from Cell Signaling; Snail (Catalog no. AB70983), pFAK (Catalog no. ab4803), and Vimentin (Catalog no. ab20346) were from Abcam; pJAK1 (Catalog no. 44422G) and pJAK2 (Catalog no. 44426G) were from Invitrogen and IL-6 (Cat # AF-206-NA) was from R&D Systems. Recombinant IL-6, IL-8, and CXCL1/GRO-alpha proteins were purchased from PeproTech Inc.

Transduction of endothelial cells with Bcl-2 and CAL27 and IOE cells with IL-6

Bcl-2 was introduced into human microvascular endothelial cells as described previously (33). Interleukin-6 (IL-6) expression plasmid IL-6–pTargetT (Promega, Madison, WI; a kind gift from Dr. Tushar Patel, The Ohio State University) containing full-length IL-6 (34) was amplified using Vent polymerase (New England Biolabs). To generate retroviral expression vector containing IL-6, the cDNA for full-length IL-6 was amplified using the forward: 5′-cggatactCAGAGGGCCATG-3′ and the reverse: 5′-tggatcAACCTCTGAGGTGCCCATG-3′ primers and the PCR product was sub cloned at the EcoRI/BamHI site of pLXSN vector (Clontech). We verified the authenticity of the expression vector by sequencing the plasmid DNA. IL-6 was introduced into CAL27 and IOE cells by using the same protocol as described above for Bcl-2 transduction.

Tumor and endothelial cell coculture

A total of 1 × 10⁵ endothelial cells overexpressing Bcl-2 (EC-Bcl-2) or endothelial cells transduced with vector alone (EC-VC cells) were layered on top of collagen coated 6-well transwell inserts (3 μmol/L, Greiner Bio-One) and these transwell inserts containing endothelial cells were then carefully placed on top of 6-well plates containing tumor cells. After 72 hours of coculture, transwell inserts were removed and CAL27 cell lysate was prepared for Western blotting. In the immunofluorescence staining experiments, CAL27 cells were cultured on top of cover slips in 6-well plates while the rest of the protocol was same as described above. For IL-6 neutralizing experiments, CAL27 cells were cocultured with EC-Bcl-2 in presence of neutralizing anti-IL-6 antibody (50 ng/mL) or isotype control antibody.

ELISA

Endothelial cells, CAL27 or IOE cells were cultured in 6-well plates till they were 80% confluent. Cells were washed and fresh media was added. After 24 hours, culture supernatants were collected from 3 separate experiments and cell number in each well was counted. Chemokines levels (IL-8, IL-6, and CXCL1/GRO-α) in culture supernatants were measured using Quantikine human ELISA kits (R&D...
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Lower chamber and 50 \times 10^5 cells were then carefully assembled on top of the wells. After 1 hour of equilibration with media, 100 \muL of cell suspension (50,000 cells/well in serum-free media) was added to each well. Cell migration to lower chamber was monitored and expressed as cell migration index at 24 hours.

**Tumor metastasis models**

CAL27 transfected with vector alone (CAL27-VC) or CAL27-IL-6 (1 \times 10^6) and endothelial cells (1 \times 10^6) were mixed with 100 \muL of Matrigel and injected subcutaneously in the flanks of SCID mice as described previously (25). Tumor volume measurements began on day 6 and continued twice a week until the end of the study. The length and width of the tumors were measured using a digital caliper and tumor volumes were calculated using the formula, volume = \frac{1}{2} \times \text{length} \times \text{width}^2. After 40 days, primary tumors, regional lymph nodes, and lungs were carefully removed. To label and identify flank draining lymph nodes, 25 \muL of 5% Evans Blue dye (Sigma) was injected in the foot pads of animals 30 minutes before euthanizing (35). Primary tumors, lymph nodes and lungs were fixed with 4% paraformaldehyde and then processed for immunohistochemistry. Tumor tissue sections were deparaffinized and antigen retrieval was achieved by pressure cooking in a Decloaking chamber at 120°C for 20 minutes (36). Slides were then washed with TBST, blocked with normal goat IgG for 1 hour, and incubated overnight at 4°C with rabbit anti-pan cytokeratin antibody (ab7753, Abcam). Nonspecific binding was blocked by incubating the blots with 3% bovine serum albumin (BSA) in Tris buffered saline containing 0.1% Tween-20 (TBST) for 1 hour at room temperature (RT). The blots were then incubated with primary antibody in TBST + 3% BSA at 4°C overnight. After washing with TBST, the blots were incubated with horseradish peroxidase-conjugated sheep anti-mouse IgG (1:10,000) or with donkey anti-rabbit IgG (1:10,000) for 1 hour at RT. An ECL-plus detection system (Amersham Life Sciences) was used to detect specific protein bands. Protein loading in all the experiments was normalized by stripping the blots and then reprobing with anti-tubulin antibody. Alpha Innotech imaging software was used to quantify Western blot bands.

**Statistical analysis**

Data from all the experiments are expressed as mean ± SEM. Statistical differences were determined by 2-way ANOVA and Student t test. A P value of < 0.05 was considered significant.

**Results**

**Bcl-2–expressing endothelial cells (EC-Bcl-2) promote EMT changes via the secretion of IL-6**

We have previously shown that Bcl-2 expression is significantly elevated in tumor-associated blood vessels of head and neck cancer patients as compared with matched control samples (27). Recently, we showed that upregulation of Bcl-2 in tumor-associated endothelial cells is sufficient to enhance tumor metastasis, in vivo (25). However, the molecular mechanism by which EC-Bcl-2 promotes tumor metastasis is poorly understood. In this study, we examined if secreted factors from EC-Bcl-2 could induce EMT-related changes in head and neck tumor cells. Indeed, coculture of...
EC-Bcl-2 along with tumor cells (CAL27) markedly enhanced vimentin expression (76% increase) while significantly decreasing E-cadherin expression (52% decrease) in CAL27 cells (Fig. 1A and B). In addition, coculture of EC-Bcl-2 with CAL27 also upregulated snail expression, a key repressor of E-cadherin (Fig. 1B). We next examined the chemokine profile of EC-Bcl-2 cells. Culture supernatants from EC-Bcl-2 cells contained significantly higher levels of IL-8, IL-6, and Gro-α as compared with endothelial cells transduced with vector alone (EC-VC; Fig. 1C). To further examine the role of these chemokines in EMT process, CAL27 cells were treated with recombinant IL-8, IL-6, or Gro-α for 3 days and E-cadherin and vimentin levels were analyzed by Western blotting. Interestingly, only IL-6 was able to significantly induce the expression of vimentin (63%) while repressing E-cadherin expression in CAL27 (51%, Fig. 1D). Similarly, coculture of CAL27 cells and EC-Bcl-2 in the presence of neutralizing IL-6 antibody significantly reversed IL-6-mediated EMT changes (Fig. 1E and F).

**IL-6 promotes EMT changes in head and neck squamous cells and immortalized oral epithelial cells**

To further examine the role of IL-6 in mediating EMT changes in HNSCCs, we cultured CAL27 cells for 3 days in the presence or absence of IL-6. IL-6 treatment of CAL27 cells markedly increased vimentin expression (62%) while at the same time decreasing the expression of E-cadherin (61%; Fig. 2A and B). IL-6 treatment also significantly increased snail expression (51%, Fig. 2B). Similarly, IL-6 treatment of IOE cells significantly upregulated the expression of vimentin (95%) and snail (64%) while reducing the E-cadherin expression (Fig 2C and D). Next, we examined the IL-6–mediated signaling cascade in CAL27 cells by treating these cells with IL-6 for different time points (0–240 min). IL-6 predominantly activated JAK/STAT3, MAPK, and PI3K/Akt signaling pathways. JAK1/2 activation peaked 10 minutes post IL-6 treatment, whereas STAT3 (pY705 and pS727), ERK1/2 and AKT activation peaked 30 minutes post IL-6 treatment (Fig. 2E).

**IL-6 overexpression in head and neck squamous cells and immortalized oral epithelial cells induces EMT changes and enhances tumor cell scattering and motility**

To further understand the role of IL-6 in the EMT process, we stably overexpressed IL-6 in CAL27 cells (CAL27-IL-6) and IOE cells (IOE-IL-6) using a retroviral vector. IL-6 expression levels in CAL27 and IOE cells were induced more than 8 fold IL-6 as compared with CAL27 cells transduced by vector alone (CAL27-VC; Supplementary Table 1). To confirm the role of IL-6 in EMT changes, we treated CAL27-IL-6 and IOE-IL-6 cells with recombinant IL-6 using ELISA and Western blotting. CAL27-IL-6 and IOE-IL-6 cells markedly increased vimentin expression (62%) and significantly decreased E-cadherin expression (52%) as compared with controls (Fig. 2A and B). IL-6 treatment also significantly increased snail expression (51%) in CAL27 (Fig. 2B). Similarly, IL-6 treatment of IOE cells significantly upregulated the expression of vimentin (95%) and snail (64%) while reducing the E-cadherin expression (Fig 2C and D). Next, we examined the IL-6–mediated signaling cascade in CAL27 cells by treating these cells with IL-6 for different time points (0–240 min). IL-6 predominantly activated JAK/STAT3, MAPK, and PI3K/Akt signaling pathways. JAK1/2 activation peaked 10 minutes post IL-6 treatment, whereas STAT3 (pY705 and pS727), ERK1/2 and AKT activation peaked 30 minutes post IL-6 treatment (Fig. 2E).

**Table 1**

<table>
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<tr>
<th>Chemokine</th>
<th>VC</th>
<th>Bcl-2</th>
<th>IL-8</th>
<th>IL-6</th>
<th>Gro-α</th>
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<tr>
<td>E-Cadherin</td>
<td>52±9.1</td>
<td>51±4.8</td>
<td>51±4.8</td>
<td>62±2.2</td>
<td>62±2.2</td>
</tr>
<tr>
<td>Vimentin</td>
<td>76±11</td>
<td>63±8.4</td>
<td>63±8.4</td>
<td>51±4.8</td>
<td>51±4.8</td>
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<tr>
<td>Snail</td>
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Interestingly, overexpression of IL-6 in CAL27 was also associated with scattering effect (Fig. 3A-a), a hallmark of EMT process. In addition, CAL27-IL-6 cells showed significantly higher vimentin (54%) and snail expression (51%) whereas E-cadherin expression was significantly reduced (53%, Fig. 3B). Furthermore, IL-6 overexpression in CAL27 cells significantly enhanced tumor cell migration (Fig. 3C).

IOE cells produced very low baseline levels of IL-6 and overexpression of IL-6 markedly increased IL-6 production (30-fold) as compared with IOE-VC (Supplementary Fig. S2A). Similar to CAL27, IL-6 overexpression induced scattering effect in IOE cells (Fig. 3D-a) and significantly increased vimentin (63%) and snail expression (70%) while downregulating E-cadherin levels (77%, Fig. 3E). In addition, IL-6 overexpression significantly enhanced IOE cell motility (Fig. 3F).

**IL-6 mediates EMT via the activation of JAK-STAT3-snail pathway**

Our signaling experiments showed that IL-6 activates 3 distinct signaling pathways: JAK/STAT3, MAPK, and PI3K/Akt (Fig. 2E). To examine which of these pathways is used by IL-6 to mediate its EMT-related effects, we knocked down Akt, STAT3, and ERK1/2 in CAL27 and IOE cells by siRNA treatment. Downregulation of Akt, STAT3, and ERK1/2 protein levels were verified by Western blotting (Fig. 4A and B). Knocking down of STAT3 in CAL27-IL-6 (Fig. 4A and C) and IOE-IL-6 cells (Fig. 4B and D) significantly reversed IL-6–mediated upregulation of vimentin (52% and 48% in CAL27-IL-6 and IOE-IL-6, respectively) and snail protein levels (58% and 64%), whereas Akt and ERK knockdown did not significantly alter vimentin and snail levels. Similarly, STAT3 knockdown significantly reversed IL-6–mediated loss of E-cadherin expression (67% and 45%), while Akt knockdown had no effect and ERK knockdown had only partial effect on E-cadherin expression (Fig. 4).

**STAT3 knockdown significantly reverses IL-6–mediated CAL27 and IOE motility by inhibiting FAK activation**

We further examined the role of different signaling pathways in IL-6–mediated tumor cell and IOE cell migration. As observed with EMT changes, knocking down of STAT3 significantly decreased CAL27-IL-6 and IOE-IL-6 cell migration (Fig. 5A and C). Knocking down of ERK had partial effect while Akt knockdown had the least effect on CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C). To further understand how STAT3 knockdown may be inhibiting CAL27 and IOE cell migration (Fig. 5A and C).

**IL-6 promotes tumor growth, EMT, and tumor metastasis in vivo**

To further investigate the role of IL-6 in EMT process and tumor metastasis, we used a SCID mouse xenograft model. CAL27-IL-6 tumors showed a moderate but
significant increase in tumor growth as compared with CAL27-VC cells (Fig. 6A). CAL27-IL-6 tumor cells exhibited fibroblastic morphology (spindle shape) in contrast to cobblestone morphology of CAL27-VC cells (Fig. 6B). In addition, CAL27-IL-6 tumors showed markedly elevated levels of activated STAT3 (pY705, Fig. 6C) and snail proteins (Fig. 6D) that were predominantly localized in the nucleus. CAL27-IL-6 tumors also showed decreased E-cadherin and increased vimentin expression (Fig. 6E and F).

Lymph nodes from animals carrying CAL27-VC tumors were negative for metastatic disease whereas 60% of lymph nodes from animals carrying CAL27-IL-6 tumors were positive for metastatic disease (Fig. 7A–C). Similarly, lungs from animals with CAL27-IL-6 tumors showed marked increase in metastatic nodes (Fig. 7D and E).

Discussion

EMT is an important biological process that plays a critical role in tumor cell metastasis and is commonly observed in tumor samples from head and neck cancer patients (37, 38). However, the precise molecular events that initiate this complex process of EMT in head and neck cancers are poorly understood. There is increasing evidence that suggests a dynamic interaction between cancer cells and the host microenvironment to support tumor growth and spread (39). Stromal fibroblasts represent a major component of tumor microenvironment and soluble factors from mammary carcinoma-associated fibroblasts were shown to induce an EMT phenotype in PMC42-LA human breast carcinoma cells (40). We have previously shown that head and neck tumors exhibit significantly higher levels of Bcl-2 expression in tumor...
associated endothelial cells (27) and overexpression of Bcl-2 alone in tumor-associated endothelial cells was sufficient to enhance tumor metastasis of oral squamous cell carcinoma in a SCID mouse model (25).

In this study, we show that endothelial cells expressing Bcl-2 (EC-Bcl-2), when cocultured with head and neck tumor cells, significantly enhance EMT-related changes in tumor cells. In addition, EC-Bcl-2 cells produced significantly higher levels of IL-8, IL-6, and Gro-α chemokines. Out of these different chemokines, only IL-6 was able to induce EMT-related changes in head and neck cancer cells. Crosstalk between endothelial cells and tumor cells via chemokines has been shown to promote transendothelial migration of cancer cells (41). Such observations reveal how cancer cells might utilize the chemokinetic network to modulate host microenvironment for their own progression. It is possible that multiple cytokines/chemokines may interact in a synergistic way to facilitate tumor cell release. In an elegant study, Lederle and colleagues, showed that IL-6 induces a complex reciprocally regulated cytokine network in tumor cells which leads to the development of malignant and invasive tumors in a human skin carcinoma model (29).

Interestingly, we also have previously observed that multiple NF-κB related serum cytokines (IL-6, IL-8, VEGF, HGF, and Gro-α) are strongly associated with poor prognosis in HNSCC patients (42). Out of these cytokines/chemokines, IL-6 was an independent predictor of tumor recurrence, poor survival and tumor metastasis (30, 31). In addition to IL-6, HGF has also been shown to regulate cell scattering and tumor metastasis in HNSCC (43).

**Figure 4.** IL-6 mediates EMT changes via the JAK/STAT3 signaling pathway. Akt, STAT3, or ERK1/2 proteins were knocked down in CAL-IL-6 and IOE-IL-6 cells by respective siRNAs. A and B, expression level of different proteins (Akt, STAT3, ERK1/2, E-cadherin, vimentin, and snail) was examined in CAL-IL-6 (A) or IOE-IL-6 (B) cells by Western blotting. Equal protein loading was verified by stripping the blots and reprobing with tubulin antibody. Band density of each protein was normalized with tubulin and expressed as % increase or decrease ± SE as compared with controls. C and D, expression levels of E-cadherin (red) and vimentin (green) was examined in CAL-IL-6 cells (C) or IOE-IL-6 cells (D) by fluorescent microscope (600×).
Therefore, we designed this study to further understand the role and mechanism(s) of IL-6–mediated EMT changes in human head and neck cancer. Our results show that IL-6 induces EMT changes in head and neck tumor cells via the activation of STAT3/Snail signaling pathway and STAT3 knockdown significantly reversed IL-6–mediated EMT changes. These results provides a mechanistic explanation for the prognostic studies that have directly linked IL-6 (30, 31), STAT3 signaling (44), and Snail (23, 45) with tumor recurrence, tumor metastasis, and poor survival in head and neck cancer patients. Recently, Sullivan and colleagues have shown that IL-6 promotes EMT changes in breast cancer by upregulating the expression of Twist (46). IL-6 is also shown to enhance human skin carcinoma cell invasiveness by inducing the overexpression of MMP-1 (29). Furthermore, as tumor cells often contain multiple genetic alterations and some of these genetic alterations may indirectly influence the IL-6 effect, we therefore examined the effect of IL-6 using immortalized IOE. Similar to tumor cells, IL-6 treatment transformed these IOE cells from typical epithelial cell phenotype to more scattered mesenchymal phenotype, a hallmark of EMT process. To our knowledge, this is the first study that has shown that IL-6 can induce EMT changes in immortalized oral epithelial cells and head and neck tumor cells.

We validated our in vitro results by implanting IL-6 overexpressing tumor cells (CAL27-IL-6) in SCID mice. Interestingly, IL-6 overexpression alone was enough to transform a nonmetastatic cell line (CAL27) into a metastatic cell line. It is possible that IL-6–mediated EMT changes may also contribute to subsequent steps of the metastatic cascade (e.g., anoikis resistance), as EMT-specific genes are known to play an important role in these metastatic steps (47, 48). Taken together, our results...
provide novel insight into the role of IL-6 in HNSCC that could explain the direct correlation observed between high serum IL-6 levels and tumor metastasis in head and neck cancer patients.

**Disclosure of Potential Conflicts of Interest**

No potential conflicts of interest were disclosed.

**References**


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