

CXCL5 Plays a Promoting Role in Osteosarcoma Cell Migration and Invasion in Autocrine- and Paracrine-Dependent Manners

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CXCL5, a CXC-type chemokine, is an important attractant for granulocytic immune cells by binding to its receptor CXCR2. Recently, CXCL5/CXCR2 has been found to play an oncogenic role in many human cancers. However, the exact role of CXCL5 in osteosarcoma cell migration and invasion has not been revealed. Here we found that the protein expression of CXCL5 was significantly increased in osteosarcoma tissues compared with that in matched adjacent nontumor tissues. Moreover, the expression of CXCL5 was significantly associated with advanced clinical stage and metastasis. Further investigation showed that the CXCL5 expression levels were also significantly increased in osteosarcoma cell lines, including Saos-2, MG63, U2OS, and SW1353, when compared with those in normal osteoblast hFoB1.19 cells. U2OS cells were further transfected with CXCL5-specific siRNA or overexpression plasmid. Knockdown of CXCL5 significantly suppressed U2OS cell migration and invasion. On the contrary, overexpression of CXCL5 remarkably promoted the migration and invasion of U2OS cells. Interestingly, both exogenous CXCL5 treatment and the conditioned medium of CXCL5-overexpressing hFoB1.19 cells could also enhance the migration and invasion of U2OS cells, suggesting that the promoting role of CXCL5 in U2OS cell migration and invasion is also in a paracrine-dependent manner. According to these data, our study demonstrates that CXCL5 is upregulated in osteosarcoma and may play an oncogenic role in osteosarcoma metastasis. Therefore, CXCL5 may become a potential therapeutic target for osteosarcoma treatment.

Key words: Osteosarcoma; CXCL5; Migration; Invasion; Metastasis

INTRODUCTION

Osteosarcoma, the most common cancer in bone, is primarily present around regions with active bone growth and repair (1,2). Despite great improvement in the diagnosis and therapy of osteosarcoma, the prognosis of osteosarcoma patients still remains poor, mainly due to its recurrence and metastasis (1,3). In recent years, many oncogenes or tumor suppressors have been found to be involved in the development and malignant progression of osteosarcoma (4,5). Therefore, revealing the underlying mechanism is of benefit to the development of diagnostic and therapeutic strategies for osteosarcoma (6).

Chemokines are secreted by various cell types including immune cells, stromal cells, and astrocytes and are classified into C, CC, CXC, and C(X)3C, according to the order of conserved cysteine residues (7,8). Various chemokines have been demonstrated to participate in biological processes such as cell invasion, differentiation, apoptosis, and migration, as well as tumorigenesis (8–10). CXCL5 is a member of the CXC subfamily of chemokines. By binding to its receptor CXCR2, CXCL5 can recruit neutrophils, promote angiogenesis, and remodel

connective tissues (11–13). Recently, deregulation of CXCL5 has been implicated in multiple types of human cancers such as gastric cancer (14), liver cancer (15), bladder cancer (16), and colon cancer (17). For instance, Zhu et al. reported that CXCL5 was upregulated in bladder cancer tissue, and high expression of CXCL5 was significantly associated with TNM stage, cancer grade, lymph node metastasis, and poor prognosis of patients with bladder cancer (16). Moreover, CXCL5 was also found to play a promoting role in the proliferation, migration, and invasion of cancer cells. For instance, Zhou et al. found that CXCR2 could promote epithelial–mesenchymal transition of hepatocellular carcinoma cells by the activation of PI3K/AKT/GSK-3 β /Snail signaling (18). In addition, the CXCL5/CXCR2 axis was found to promote the migration and invasion of bladder cancer cells by enhancing the PI3K/AKT-induced upregulation of MMP2 and MMP9 (19). Accordingly, CXCL5 may become a potential therapeutic target for human cancer. However, the underlying mechanism of CXCL5 in mediating the migration and invasion of osteosarcoma cells remains largely unclear.

Therefore, our study investigated the expression and clinical significance of CXCL5 in osteosarcoma. We also studied the exact role of CXCL5 in regulating the migration and invasion of osteosarcoma cells.

MATERIALS AND METHODS

Clinical Specimens

The study was approved by the Ethics Committee of Taihe Hospital, Shiyuan, P.R. China. A total of 38 primary osteosarcoma tissues and matched adjacent nontumor tissues were collected at our hospital. The histomorphology of all samples was confirmed by the Department of Pathology of our hospital. All written consents were obtained. Before surgical resection, no patient received radiotherapy or chemotherapy. Tissue samples were stored at -80°C before use.

Cell Cultures

Human osteosarcoma cell lines including Saos-2, MG63, U2OS, and SW1353, and normal human osteoblast hFoB1.19 cells were purchased from the Cell Bank of the Chinese Academic Institute, Shanghai, P.R. China. All cell lines were cultured in DMEM (Gibco, USA) added with 10% FBS (Gibco, USA) in a 37°C humidified incubator with 5% CO_2 .

Cells Transfection

The pcDNA-3.1-CXCL5 ORF plasmid or CXCL5 siRNA was respectively transfected into cells using Lipofectamine 2000 (Life Technologies, USA) according to the manufacturer's instruction. Briefly, cells were cultured to 70% confluence and resuspended in serum-free DMEM. The plasmid or siRNA and Lipofectamine

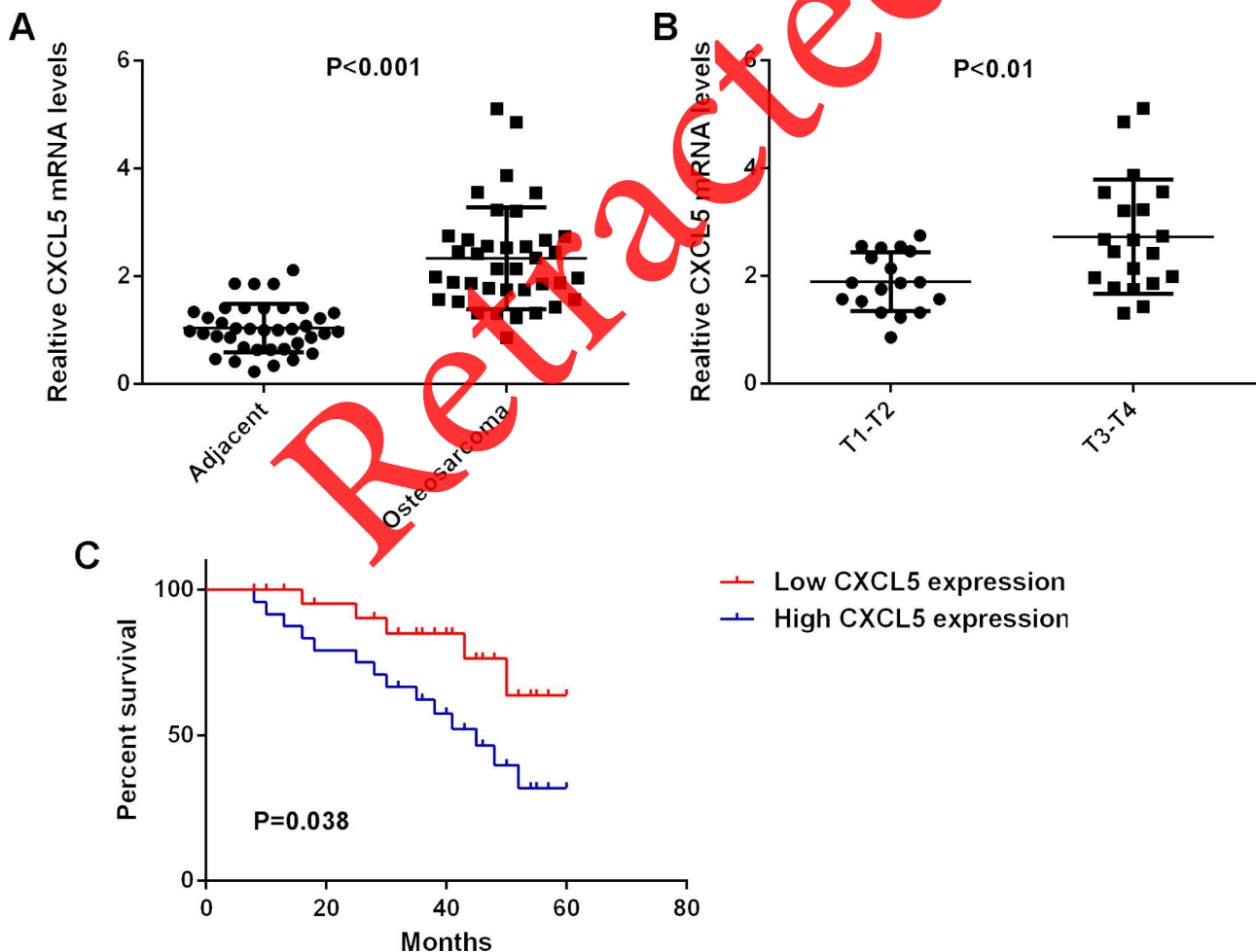


Figure 1. (A) Real-time PCR was conducted to examine the mRNA expression of CXCL5 in osteosarcoma tissues compared to normal adjacent tissues. (B) Real-time PCR was conducted to examine the mRNA expression of CXCL5 in T3–T4 osteosarcoma tissues compared to T1–T2 osteosarcoma tissues. (C) Osteosarcoma patients with high CXCL5 expression showed shorter survival time compared to those with low CXCL5 expression.

2000 were diluted with serum-free medium, respectively. The diluted Lipofectamine 2000 was then added into the diluted plasmid or siRNA, incubated for 20 min at room temperature, and then added into the cell suspension. After incubation at 37°C for 6 h, the medium was replaced by the normal serum-containing medium. Then cells were cultured for 48 h before the following assays.

RT-PCR Analysis

Total RNA was extracted using TRIzol reagent (Life Technologies) and then converted into cDNA using the Reverse Transcription Kit (Life Technologies) according to the manufacturer's instruction. Real-time PCR was then performed using Q-PCR Detection Kit (Life Technologies) on the ABI 7500 thermocycler. The PCR steps were 95°C for 10 min, and 40 cycles of denaturation at 95°C for 15 s, and the annealing/elongation step at 60°C for 60 s. GAPDH was used as an internal control. The relative expression was analyzed by the $2^{-\Delta\Delta Ct}$ method.

Western Blotting

Cells were lysed with ice-cold lysis buffer [50 mM Tris-HCl, pH 6.8, 100 mM 2-ME, 2% (w/v) SDS, 10% glycerol]. Protein was separated with 10% SDS-PAGE and then transferred onto a polyvinylidene difluoride (PVDF) membrane (Life Technologies). The PVDF membrane was incubated with PBS containing 5% milk overnight at 4°C. After washing with PBS three times, the PVDF membrane was incubated with primary antibodies (Abcam, Cambridge, MA, USA) at room temperature for 3 h. After washing with PBS three times, the PVDF membrane was incubated with secondary antibody (Abcam) at room temperature for 1 h. Super Signal West

Pico Chemiluminescent Substrate Kit (Pierce, Rockford, IL, USA) was then used to detect signals, according to the manufacturer's instruction. The relative protein expression was analyzed by Image-Pro Plus software 6.0, represented as the density ratio versus GAPDH.

Enzyme-Linked Immunosorbent Assay (ELISA)

Cells in DMEM containing 10% FBS were seeded in a six-well plate (1.5×10^5 cells/well) and cultured for 48 h. Then the supernatant was collected and centrifuged at $12,000 \times g$ for 10 min. The secretion level of CXCL5 was detected using a human CXCL5 ELISA kit (Thermo Fisher, USA) according to the manufacturer's instructions.

Wound-Healing Assay

Wound-healing assay was used to examine the cell migration. U2OS cells in each group were cultured to full confluence, and a wound of approximately 1-mm width was created with a plastic scribe. The U2OS cells were washed and then cultured in DMEM containing 10% FBS for 48 h. Then cells were observed and photographed under a microscope.

Transwell Assay

Transwell assay was performed to examine the cell invasion using Transwell chambers (BD, USA). U2OS cell suspension containing 5×10^5 cells/ml was prepared in serum-free media, and 300 μ l of cell suspension was added into the upper chamber. Then 500 μ l of DMEM with 10% FBS was added into the lower chamber. Cells were incubated for 24 h. We used a cotton-tipped swab to carefully wipe out the cells that did not invade through the pores. The filters were fixed in 90% alcohol, stained

Table 1. Correlation Between CXCL5 Expression and Clinicopathologic Features of Patients With Osteosarcoma

Variables	Cases (n=38)	CXCL5 Expression		p Value
		High (n=18)	Low (n=20)	
Gender				0.752
Male	22	11	11	
Female	16	7	9	
Age (years)				0.741
≤ 28	23	10	13	
> 28	15	8	7	
Tumor size (diameter)				0.516
≤ 5 cm	18	10	8	
> 5 cm	20	8	12	
WHO grade				0.028
I and II	18	5	13	
III and IV	20	13	7	
Distant metastasis				0.042
Positive	14	10	4	
Negative	24	8	16	

by crystal violet, and observed under an inverted microscope (Olympus, Tokyo, Japan).

Statistical Analysis

The results are expressed as the mean \pm SD of three independent experiments. SPSS.21 was used to perform statistical analysis. Student's *t*-test was used to analyze the difference between two groups. One-way analysis of variance (ANOVA) was used to analyze the differences among more than two groups. A value of $p < 0.05$ was considered statistically significant.

RESULTS

CXCL5 Is Upregulated in Osteosarcoma Tissues and Cell Lines

In the present study, the protein expression of CXCL5 was determined in osteosarcoma tissues and matched adjacent nontumor tissues using ELISA. Our data indicated that CXCL5 levels were significantly increased in osteosarcoma tissues compared with those in their matched adjacent nontumor tissues (Fig. 1A). The clinical significance of CXCL5 expression in osteosarcoma was further investigated. According to the mean expression value of CXCL5, these osteosarcoma patients were divided into two groups: the high CXCL5 expression group and the low CXCL5 expression group. Our data showed that the increased expression of CXCL5 was significantly associated with advanced clinical stage and metastasis of

osteosarcoma, but was not associated with age, sex, or tumor size (Table 1). Moreover, we found that the osteosarcoma patients with high CXCL5 expression showed shorter survival time when compared with those with low CXCL5 expression (Fig. 1B). Accordingly, the increased expression of CXCL5 is associated with advanced progression and poor prognosis in osteosarcoma patients.

We then detected the mRNA and protein levels of CXCL5 in osteosarcoma cell lines, including U2OS, U251, U373, and A172, and normal human osteoblast hFoB1.19 cells. As indicated in Figure 2A and B, the mRNA and protein expression of CXCL5 were also upregulated in these osteosarcoma cell lines when compared with those in hFoB1.19 cells.

Knockdown of CXCL5 Decreases the Migration and Invasion of Osteosarcoma Cells

As U2OS showed the highest expression of CXCL5, we used this cell line in the following experiments in vitro. The regulatory role of CXCL5 in osteosarcoma cell migration and invasion was then studied. U2OS cells were transfected with CXCL5-specific siRNA to decrease its expression. Nonspecific siRNA was used as a negative control (NC). After transfection for 48 h, real-time qPCR and Western blot were conducted to examine the mRNA and protein level of CXCL5 in U2OS cells. As shown in Figure 3A and B, transfection with CXCL5-specific siRNA caused a significant decrease in the mRNA and protein expression of CXCL5 in U2OS cells, when compared to the NC group. We then

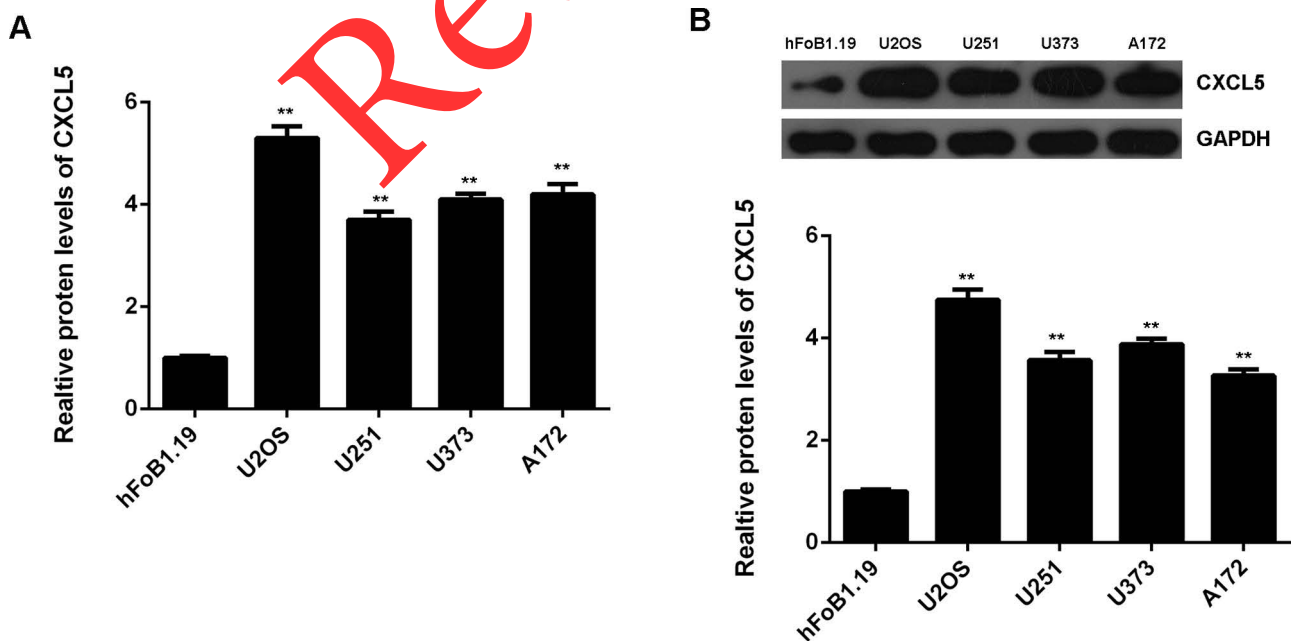


Figure 2. (A) Real-time PCR and (B) Western blot were conducted to examine the mRNA and protein expression of CXCL5 in osteosarcoma cell lines including Saos-2, MG63, U2OS, and SW1353, and normal human osteoblast hFoB1.19 cells. ** $p < 0.01$ versus hFoB1.19.

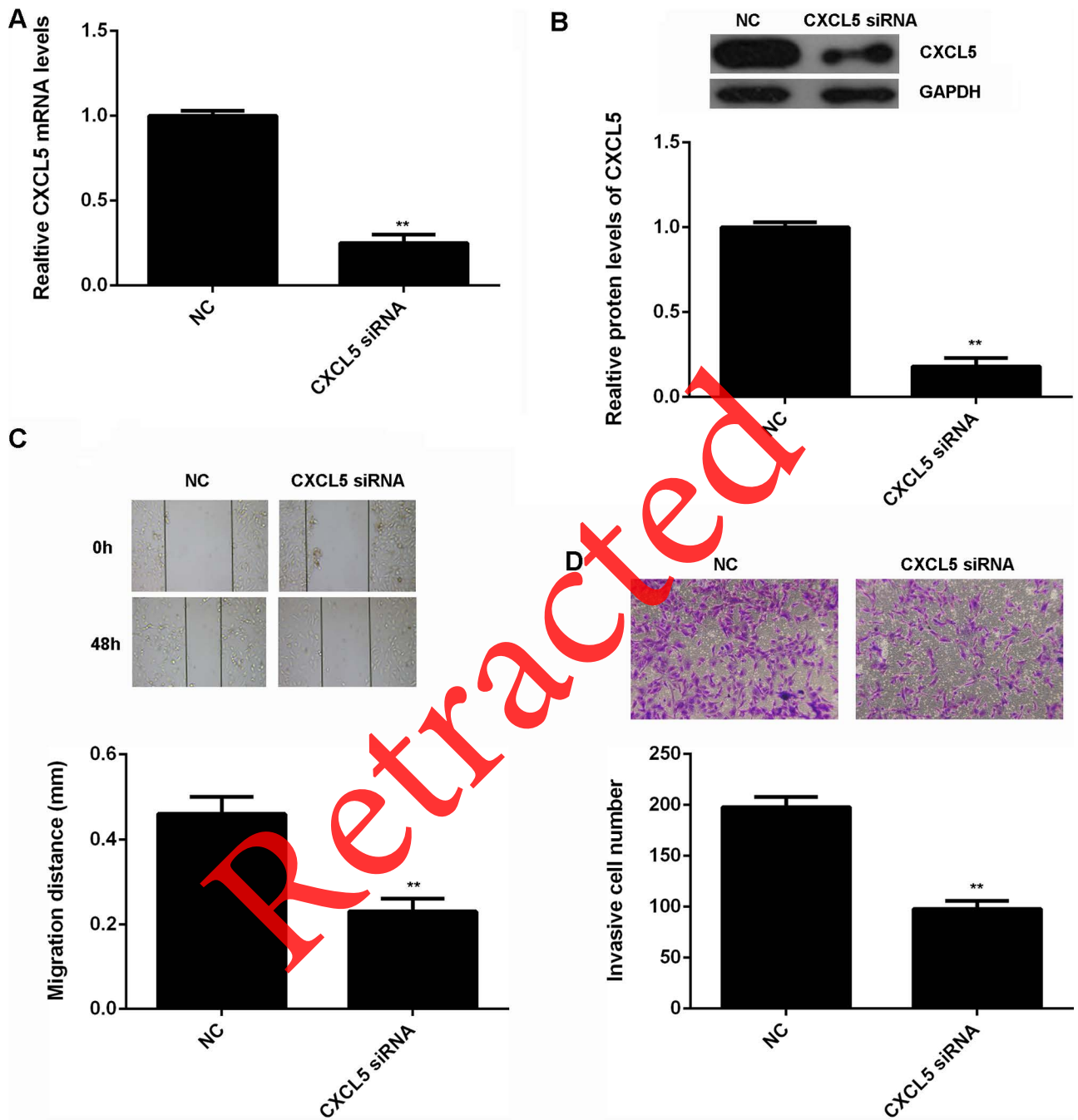


Figure 3. (A) Real-time PCR and (B) Western blot were conducted to examine the mRNA and protein expression of CXCL5 in U2OS cells transfected with CXCL5 siRNA or nonspecific siRNA as negative control (NC), respectively. (C) Wound-healing assay and (D) Transwell assay were used to determine cell migration and invasion. ** $p < 0.01$ versus NC.

used wound-healing assay and Transwell assay to examine cell migration and invasion. As shown in Figure 3C and D, knockdown of CXCL5 led to a remarkable decrease in the migration and invasion of U2OS cells.

To further confirm these findings, U2OS cells were transfected with CXCL5 expression plasmid to upregulate

its expression. Cells transfected with blank vector were used as the control. We found that the mRNA and protein levels of CXCL5 were significantly increased after transfection with CXCL5 expression plasmid (Fig. 4A and B). Moreover, wound-healing assay and Transwell assay data showed that the migration and invasion capacities

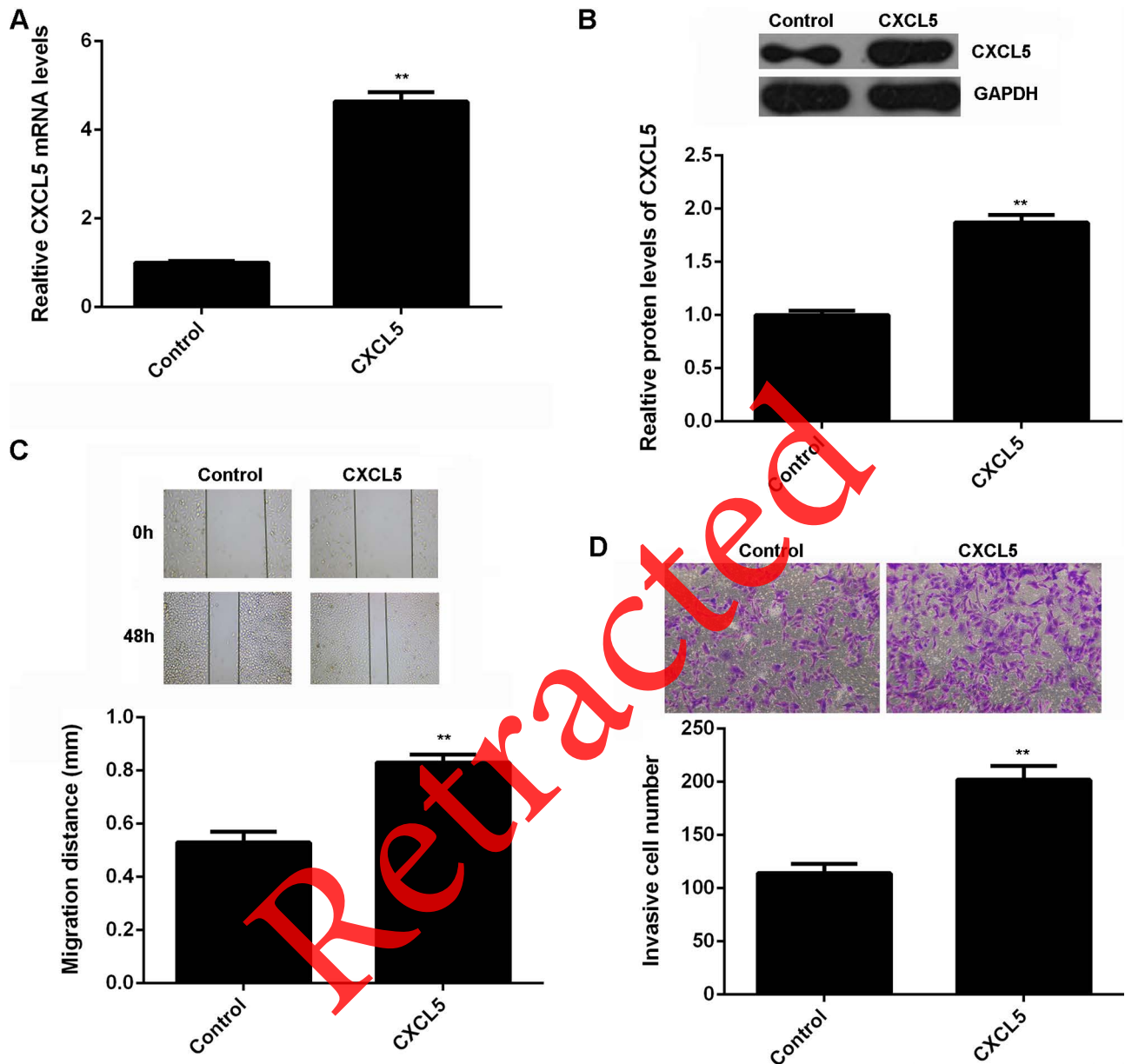
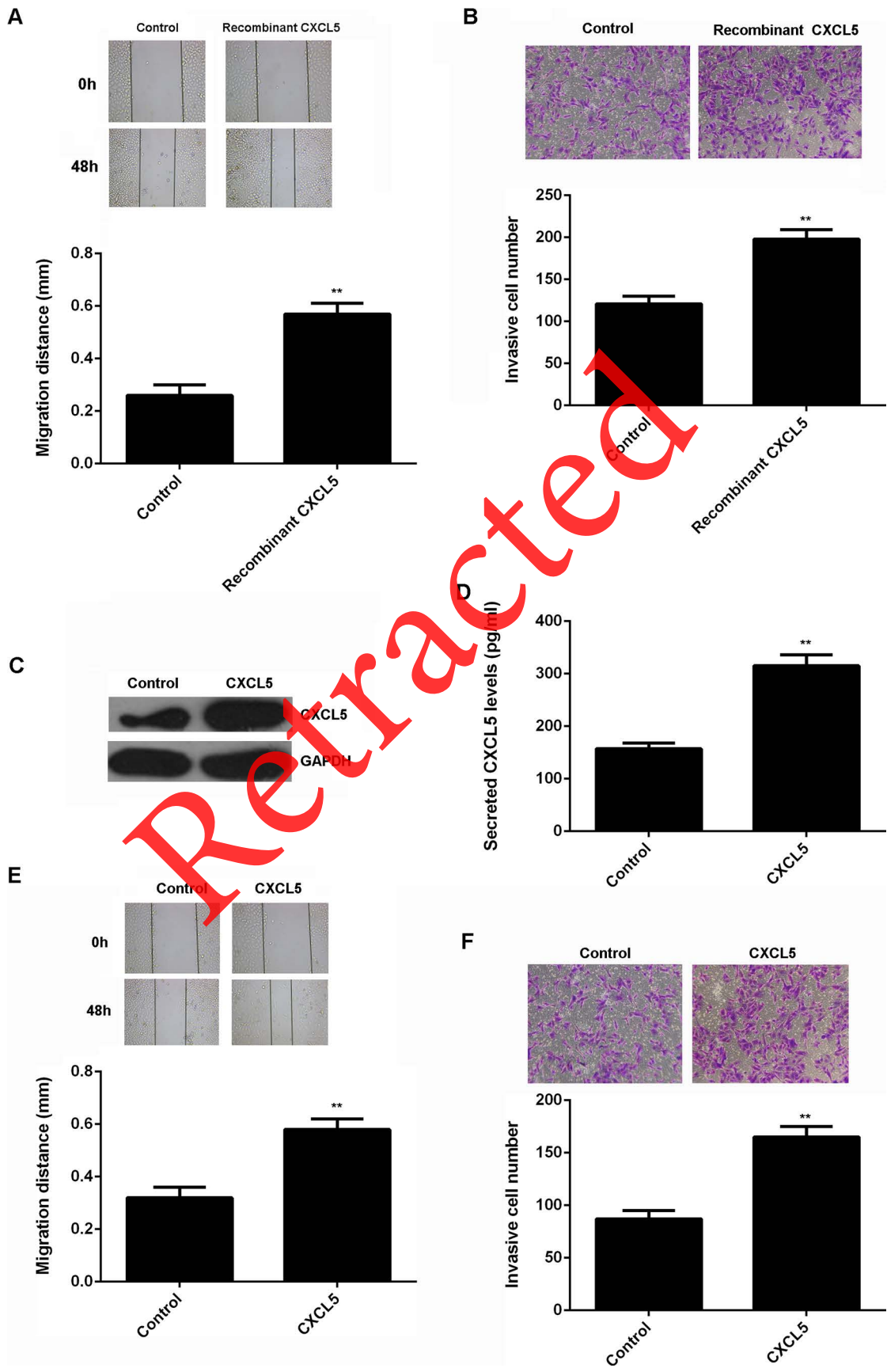


Figure 4. (A) Real-time PCR and (B) Western blot were conducted to examine the mRNA and protein expression of CXCL5 in U87 cells transfected with CXCL5 expression plasmid or blank vector as control, respectively. (C) Wound-healing assay and (D) Transwell assay were used to determine cell migration and invasion. ** $p < 0.01$ versus Control.

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Figure 5. (A) Wound-healing assay and (B) Transwell assay were used to determine the migration and invasion of U2OS cells treated with recombinant human CXCL5. Nontreated U2OS cells were used as the control group. ** $p < 0.01$ versus Control. (C) Western blot and (D) ELISA were conducted to examine the protein expression and secreted protein levels of CXCL5 in hFoB1.19 cells transfected with CXCL5 expression plasmid or blank vector as control. ** $p < 0.01$ versus Control. We further used the CM of these hFoB1.19 cells to culture U2OS cells. (E) Wound-healing assay and (F) Transwell assay were used to determine the migration and invasion of U2OS cells. ** $p < 0.01$ versus Control.



of U2OS cells were significantly upregulated after overexpression of CXCL5 (Fig. 4C and D). On the basis of these data, we suggest that CXCL5 can promote the migration and invasion of osteosarcoma cells.

CXCL5 Also Plays a Promoting Role in Osteosarcoma Cell Migration and Invasion in a Paracrine-Dependent Manner

As CXCL5 is also produced by other normal cells in the bone, we examined the effect of recombinant human CXCL5 on the migration and invasion of U2OS cells. Our data indicated that treatment with recombinant human CXCL5 could also promote the migration and invasion of U2OS cells (Fig. 5A and B). To further examine the effect of normal cell-derived CXCL5 in the bone on osteosarcoma growth and metastasis, hFoB1.19 cells were transfected with CXCL5 expression plasmid. After transfection, the protein expression of CXCL5 was significantly increased (Fig. 5C). Moreover, ELISA data indicated that the CXCL5 protein levels in the conditioned medium (CM) of CXCL5-overexpressing hFoB1.19 cells were also higher compared to those in the NC group (Fig. 5D). U2OS cells were further cultured using the CM of CXCL5-overexpressing hFoB1.19 cells. The CM of hFoB1.19 cells transfected with blank vector was used as control. The cell migration and invasion were further studied. As indicated in Figure 5E and F, the migration and invasion of U2OS cells cultured with the CM of CXCL5-overexpressing hFoB1.19 cells were significantly increased. These findings suggest that CXCL5 may also play a promoting role in osteosarcoma in a paracrine-dependent manner.

DISCUSSION

CXCL5/CXCR2 signaling plays a promoting role in some common human cancers (15, 20–22), but the exact role of CXCL5 in osteosarcoma cell migration and invasion, as well as the underlying mechanism, remains unclear. In the present study, we found that CXCL5 was upregulated in osteosarcoma tissues compared with that in matched adjacent nontumor tissues. High CXCL5 levels were significantly associated with advanced clinical stage and metastasis. Further investigation showed that the expression levels of CXCL5 were also significantly increased in osteosarcoma compared with those in normal osteoblast cells. In vitro study indicated that knockdown of CXCL5 significantly suppressed the migration and invasion of osteosarcoma U2OS cells. On the contrary, overexpression of CXCL5 remarkably promoted the migration and invasion of U2OS cells. Interestingly, both exogenous CXCL5 treatment and the CM of the CXCL5-overexpressing osteoblasts could also enhance the migration and invasion of U2OS cells, suggesting that the promoting role of CXCL5 in U2OS cell migration and invasion is also in a paracrine-dependent manner.

Recently, deregulation of CXCL5 has been implicated in human cancers. Dimberg et al. reported that CXCL5 was significantly upregulated in colorectal tumor tissues compared to normal mucosa tissues (17). The expression of CXCL5 was also markedly increased in late-stage gastric cancer, and its upregulation was significantly correlated with higher microvascular density (14). In addition, Zhu et al. reported that CXCL5 was upregulated in both urine and tumor tissue of bladder cancer patients, and the increased CXCL5 expression was significantly correlated with tumor size, grade, TNM stage, lymph node metastasis, and poor prognosis of patients with bladder cancer (16). In the present study, for the first time, we showed that the expression of CXCL5 was significantly upregulated in osteosarcoma tissues compared to matched adjacent nontumor tissues, and its high expression was significantly associated with poor differentiation, advanced clinical stage, metastasis, and poor prognosis of osteosarcoma patients. Our data suggest that increased CXCL5 expression contributes to disease progression in osteosarcoma. In addition, the expression levels of CXCL5 were significantly increased in osteosarcoma cell lines compared to those in normal osteoblast hFoB1.19 cells. Therefore, we suggest that the CXCL5/CXCR2 signaling is activated in osteosarcoma.

Previous studies have demonstrated that CXCL5 plays a promoting role in the malignant phenotypes of cancer cells. For instance, siRNA-induced downregulation of CXCL5 caused a significant decrease in cell proliferation, migration, and invasion in head and neck squamous cell carcinoma in vitro, as well as the tumorigenic potential in vivo (23). Gao et al. reported that the CXCL5/CXCR2 axis promotes bladder cancer cell migration and invasion by activating PI3K/AKT-induced upregulation of MMP2/MMP9 (19), and knockdown of CXCL5 expression inhibits the proliferation and migration of bladder cancer cells (24). As osteosarcoma U2OS cells showed the highest expression of CXCL5 among all these osteosarcoma cell lines involved in this study, we used this cell line in the following in vitro studies. To further investigate the role of CXCL5 in osteosarcoma cell migration and invasion, U2OS cells were transfected with CXCL5-specific siRNA or CXCL5 expression plasmid to knock down or upregulate its expression, respectively. We found that knockdown of CXCL5 caused a significant reduction in the migration and invasion of U2OS cells. On the contrary, overexpression of CXCL5 markedly promoted the migration and invasion of U2OS cells. Therefore, we suggest that CXCL5 may have promoting effects on osteosarcoma growth and metastasis, making it a potential therapeutic target for the treatment of osteosarcoma.

CXCL5 is secreted by different cell types, such as immune cells, stromal cells, and astrocytes (25–27). For instance, Dimberg et al. examined the expression of CXCL5 in colorectal carcinoma using immunohistochemistry and

found that the CXCL5 immunoreactivity was mainly in epithelial cells of the colorectal carcinoma and in normal epithelial cells (17). Therefore, we speculated that CXCL5 might also promote the migration and invasion of osteosarcoma cells in a paracrine-dependent manner, not only in an autocrine manner. To verify this speculation, we first used recombinant human CXCL5 to treat U2OS cells. Our data indicated that the exogenous CXCL5 could also promote the migration and invasion of U2OS cells. To further confirm our speculation, we used the CM of CXCL5-overexpressing hFoB1.19 cells to culture the U2OS cells. Our data demonstrated that the CM of CXCL5-overexpressing hFoB1.19 cells enhanced the migration and invasion of U2OS cells. Therefore, these data suggest that CXCL5 also plays a promoting role in osteosarcoma cell migration and invasion in a paracrine-dependent manner.

In conclusion, our study demonstrates that CXCL5 plays a promoting role in osteosarcoma cell migration and invasion in autocrine- and paracrine-dependent manners. Therefore, CXCL5 may be a potential therapeutic target for the treatment of osteosarcoma.

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