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ORIGINAL RESEARCH

RETRACTED ARTICLE: OCT4 accelerates tumorigenesis through activating JAK/STAT signaling in ovarian cancer side population cells

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Background: Although surgery, chemotherapy, and radiotherapy eliminate clinically apparent ovarian tumor, the 5-year survival rate is no more than 45%. Cancer stem cells (CSCs) have been identified for precaution of tumor metastasis and recurrence in many kinds of carcinomas including ovarian cancer.
Aim: This study aims to explore the function of OCT4, a CSC marker, in ovarian cancer progression and to investigate its underlying mechanism.
Materials and methods: By Hoechst side population (SP) technique, CSC-like SP cells from human ovarian cancer SKOV3 and A2780 cells were isolated and used for this study. shRNA and lentivirus targeting human *OCT4* gene were used to knock down OCT4 in SP cells and upregulate OCT4 in non-SP (NSP) cells stably. Peficitinib was used to inhibit JAK/STAT signaling. Cell counting kit-8, flow cytometry, and in vivo xenograft model were used to evaluate the effects of OCT4/JAK/STAT on cell viability, drug resistance, apoptosis, cycle, and tumorigenesis of the SP cells. Immunofluorescence staining was used to detect the location of STAT6.
Results: Results showed that OCT4 was upregulated in the SP of SKOV3 and A2780 cells when compared with the NSP cells. Downregulation of OCT4 inhibited SP cell viability, tumorigenesis, and reduced cell drug resistance and induced a G2/M phase arrest, while upregulation of OCT4 conferred NSP cell malignant features. Besides, OCT4 upregulation in NSP cells increased the phosphorylated levels of proteins in JAK and STAT families, especially in JAK1 and STAT6. Furthermore, the roles of apoptosis inhibition and viability, invasion, and tumorigenesis promotions induced by OCT4 in NSP cells were all abolished when adding peficitinib.
Conclusion: Our study demonstrated that OCT4 accelerated ovarian cancer progression through activating JAK/STAT signaling pathway.
Keywords: OCT4, JAK/STAT signaling, ovarian cancer, side population

Introduction

Ovarian cancer is one of the most common gynecologic malignances in China, with potentially lethal consequences; in 2015, 52,100 new cases and 22,500 deaths were reported.[1] High-grade serous ovarian carcinomas, an aggressive subtype of ovarian cancer, account for 70% of ovarian cancer and are associated with low survival rates.[2] Although surgery, chemotherapy, and radiotherapy eliminate clinically apparent tumors, the 5-year survival rate is no more than 45%.[3] Therefore, there is an urgent need to characterize the molecular pathogenesis of ovarian carcinoma.

Evidences have suggested that the recurrence of ovarian cancer may be activated by a subpopulation of tumor cells that exhibit stem cell-like traits[4,5] and were named as cancer stem cells (CSCs). These cells not only display enhanced self-renewal traits like embryonic stem cells (ESCs) but also exhibit drug resistance and tumorigenic survival characteristics.[6–9]

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Thus, keeping a watchful eye on CSC population has been served as a novel strategy to avoid chemoresistance or tumor recurrence.[10,11] How to eradicate CSCs to improve the survival of ovarian cancer patients after surgery with or without radio-/chemotherapy becomes a challenging issue.

The reports related to CSCs in many kinds of cancer scenarios including ovarian cancer have been accumulating for the last 10 years. Several potential indirect mechanisms of CSC regulation have been proposed, such as the Ras/Raf/MEK/ERK, Notch, Hedgehog, phosphatidylinositol 3-hydroxy kinase/AKT (PI3K/AKT), and Janus-activated kinase (JAK)/STAT signaling pathways.[12–16]

OCT4 (POU class 5 homeobox 1, POU5F1), a transcription factor, has the potential to maintain self-renewal and pluripotency in ESCs and primordial germ cells.[17,18] OCT4A and OCT4B are the two transcript variants, which are encoded by OCT4 gene; they share a common carboxyl-terminus of 225 amino acids but consist of 360 and 255 amino acids, respectively.[19] Generally, OCT4B is located in the cytoplasm, while OCT4A is located in the nucleus and has been associated with properties to maintain ESCs and primordial germ cells in an undifferentiated state and stem cell properties.[19] Recently, Samardzija et al[20] have found that knockdown of OCT4A caused the obvious alterations in protein networks associated with cytoskeleton, metabolism, adhesion, proliferation, epithelial–mesenchymal transition, CSCs, and drug resistance in ovarian cancer. However, the specific roles of OCT4 and its underlying molecular mechanism in the progression of ovarian cancer have not yet been completely elucidated.

Therefore, this study aims to explore the function of OCT4 in ovarian cancer progression and investigate its underlying mechanism. CSC-like side population (SP) cells excluded from the Hoechst 33342 were used to build OCT4 knockdown cell model, and non-SP (NSP) cells were used to build OCT4 overexpression cell model. First, we determined the expression of OCT4 in SP cells and explored its function in the growth, drug resistance, cycle, and tumorigenesis of ovarian cancer cells. Next, we searched the signaling pathway related to OCT4 in regulation of ovarian cancer cell malignant phenotype transformation. Finally, we studied the effects of OCT4 and its activated signaling pathway in the progression of ovarian cancer.

Materials and methods

Cell lines and cell culture

The human ovarian cancer cell lines SKOV3 and A2780 were obtained from the American Type Culture Collection (ATCC, Manassas, VA, USA); SKOV3 cells were grown in McCoy's 5a modified medium (Biological Industries, Kibbutz BeitHaemek, Israel), while A2780 cells were cultured in DMEM (BI), containing 10% FBS (Thermo Fisher Scientific, Waltham, MA, USA) and 100 U/mL of penicillin (Thermo Fisher Scientific), as well as 100 µg/mL of streptomycin sulfate (Thermo Fisher Scientific). And the cells were cultured in a humidified 5% CO_2 atmosphere at 37°C.

Cell transfection and RNA interference

For knockdown of the expression of OCT4 stably, the shRNAs targeting human OCT4 (No. TR310267) gene was purchased from OriGene (Rockville, MD, USA). Peficitinib, an inhibitor of JAK, was purchased from MedChemExpress (Shanghai, China) and used to repress JAK/STAT signaling. For upregulation of OCT4, the lentivirus GV358-OCT4 (No. RC211998L1, OriGene) was used.

RNA extraction and real-time PCR (RT-PCR)

Total RNA from SKOV3 or A2780 cells was obtained using TRIzol reagent (Thermo Fisher Scientific) when the cells reached confluence of 90%, referring to the manufacturer's instructions. The ThermoScript reverse-transcription PCR system (Promega Corporation, Fitchburg, WI, USA) was used to reverse RNA to cDNA, according to the manufacturer's protocols. Quantitative RT-PCR was carried out by SYBR Green PCR master mix (Qiagen NV, Venlo, the Netherlands) in a 20 µL reaction system on a DA7600 Real-time Nucleic Acid Amplification Fluorescence Detection System (Bio-Rad Laboratories Inc., Hercules, CA, USA). The primers used were as follows: OCT4, 5′-ATGTGGTCCGAGTGTGGTTC-3′ (forward) and 5′-GAGACAGGGGGAAAGGCTTC-3′ (reverse); GAPDH, 5′-ATCATCCCTGCCTCTACTGG-3′ (forward) and GAPDH, 5′-GTCAGGTCCACCACTGACAC-3′ (reverse).

Western blotting analysis

Total proteins from cells were extracted using RIPA buffer containing protease inhibitor (Beyotime Institute of Biotechnology, Shanghai, China). The concentration of proteins in the sample was detected by a BCA protein assay kit (Thermo Fisher Scientific). The proteins from different groups were separated by 10% SDS-PAGE and electrotransferred to a polyvinylidene fluoride (PVDF) membrane (Merck Millipore, Billerica, MA, USA). Then, the PVDF membrane was then blocked with 5% nonfat milk for 1 hour and incubated with primary antibodies overnight at 4°C. Next day, the PVDF membrane was washed with 3× TBST, followed by incubation for 1 hour with horse

radish peroxidase-labeled secondary antibodies diluted with 5% nonfat milk. For quantification, the protein bands were detected using an ECL system (Merck Millipore). GAPDH was used as an endogenous control for total protein. The primary antibodies in this study were all purchased from Abcam (CA, USA).

Cell counting kit-8 (CCK-8) assay

Cell proliferation was detected by using a CCK-8 assay (Dojindo, Tokyo, Japan); 1×10^3 SKOV3 or A2780 cells were seeded in 96-well plates in triplicate. Cell proliferation was monitored at indicated times (24, 48, 72, 96, and 120 hours). After incubation for the designated times, 10 µL of CCK-8 solution was added to each well and incubated for 3 hours and the absorbance at 450 nm was determined by a microplate reader (Bio-Rad Laboratories Inc.).

Clone formation assay

Cells given different treatments were routinely digested with trypsin during the logarithmic growth phase. Then, cells were resuspended at 200 cells/mL with culture medium containing 10% FBS and seeded into a 6-well plate at 1 mL/well. Next, 3 mL of 10% FBS medium was added to each well and incubated for 14 days. Next, cells were washed with PBS thrice and fixed with 4% paraformaldehyde for 15 minutes and stained with 0.1% crystal violet solution for 20 minutes. The number of colonies was counted directly under a microscope.

Cell apoptosis

After being treated with different treatments for 48 hours, the SKOV3 or A2780 cells were harvested and stained with propidium iodide (PI) and Annexin V-FITC (KeyGen, Nanjing, China) followed by detection with the BD-FACSCanto™ II (BD Bioscience, San Jose, CA, USA) for flow cytometry analysis. The percentage of cell apoptosis population was evaluated by FlowJo 7.6 software.

Cell cycle

For cell cycle analysis, SKOV3 or A2780 cells were synchronized with serum-free media for 12 hours. Then, the floating and attached cells were collected and fixed in 70% ethanol at 4°C for 3 hours after 48 hours of the treatment. Next, the cells were treated with RNase (20 µg/mL) at 37°C for 30 minutes and stained with PI using PI-staining buffer at a concentration of 5 µg/mL (KeyGen) at 4°C for 30 minutes in the dark. The stained cells were analyzed by BD-FACSCanto II to calculate the percentages of cells in various phases of cell cycle by using FlowJo 7.6 software. At least 1×10^5 cells were counted for each test.

SP analysis

For SP analysis, SKOV3 or A2780 cells were trypsinized and suspended at a density of 1×10^6 cells/mL in McCoy's 5a with 2% FBS. Then, the cells were stained with 5 µg/mL of Hoechst 33342 at 37°C for 90 minutes. Next, the cells were centrifuged and suspended in ice-cold PBS with 2% FBS containing 2 µg/mL PI. The flow cytometry analysis was performed using the LSRFortessa cell analyzer (BD Biosciences, San Jose, CA, USA). The data were analyzed by FlowJo 7.6 software. To detect the expression of OCT4 in the SP and NSP of SKOV3 or A2780 cells, the SKOV3 or A2780 cells sorted using the BD FACSAria II cell sorter (BD Biosciences) were used for Western blotting and RT-PCR analysis.

Cell invasion

For cell invasion assay, 24-well transwell plate (8.0 µm, Corning Incorporated, Corning, NY, USA) was used to measure cell invasive capability with different treatments. Briefly, the upper surface of the membrane was pre-coated with Matrigel basement membrane matrix (BD Biosciences); 1×10^5 SKOV3 or A2780 cells were resuspended in 200 µL medium with 2% FBS and seeded into the upper chambers, and 600 µL complete medium supplemented with 10% FBS was added into the lower chamber as a chemoattractant. After 48 hours of incubation, the invading cells attached to the lower surface were fixed, stained, and counted.

Immunofluorescence staining

Immunofluorescence staining was performed in accordance with a previous study.[21] Briefly, cells were seeded at 10% confluence onto small glass coverslips placed in 24-well plates. Twelve hours later, different treatments were performed and then the coverslips were removed, washed with 3× PBSs, and fixed with 4% paraformaldehyde in PBS for 15 minutes. After pushing through the cytomembrane (0.1% Triton, 0.1% sodium citrate for 10 minutes) and blocking in 5% goat serum for 1 hour, the cells were incubated with STAT6 primary antibodies (1:100) overnight at 4°C. After washing with 3× PBS, the cells were incubated with a 1:500 dilution of a fluorescent tag (Alexa Fluor 488; Thermo Fisher Scientific) and conjugated with secondary antibodies for 30 minutes in the dark. Next, the cells were treated with DAPI (1:10,000, Invitrogen) for 5 minutes, washed 3× with PBST, covered with an antifade mounting medium, and placed onto microscope slides. The location of STAT6 was measured using a laser scanning microscope (TCS SP2-AOBS-MP; Leica Microsystems, Wetzlar, Germany).

Xenograft model

At the age of 4 weeks, 5×10^6 SKOV3/A2780 SP cells treated with sh-NC or sh-OCT4 or NSP cells treated with Lentiv-NC, Lentiv-OCT4, or Lentiv-OCT4+ peficitinib were injected subcutaneously into the armpit skin of female nude mice (BALB/c-nu/nu, Jackson Laboratory, Beijing, China). The engrafted mice were inspected every day by visual observation and palpation. After 28 days, the animals were euthanized by cervical dislocation. The tumors were isolated and evaluated by the weight. All procedures involving animals and their care were conducted in conformity with the National Institutes of Health Guide for Care and Use of Laboratory Animals (NIH Pub. No. 85-23, revised 1996) and was approved by Animal Care and Use Committee of the International Peace Maternity and Child Health Hospital, School of Medicine, Shanghai Jiaotong University, Shanghai, China.

Statistical analyses

Each experiment was performed at least three times. Statistical analyses, including two-tailed tests, unpaired Student's *t*-tests, and a one-way ANOVA, were performed using SPSS 23.0. Mann–Whitney *U* tests were conducted to analyze non-normally distributed data sets. *P*-values <0.05 were considered significant.

Results

OCT4 is highly expressed in the SP of ovarian cancer cells

To explore the effects of OCT4 in the progression of ovarian cancer, we sorted the SP population of SKOV3 and A2780 cells (excluded the Hoechst 33342 dye). Results showed that both the mRNA and protein expression of OCT4 were significantly elevated in the SP cells when compared with that in the NSP population, which were determined by Western blotting (Figure 1A) and RT-PCR analysis (Figure 1B), respectively. The data indicated that OCT4 might play an important role in the stemness and drug resistance in ovarian cancer.

Downregulation of OCT4 alleviates cell drug resistance and inhibits cell proliferation and tumorigenesis in the SP of ovarian cancer cells

Next, we investigated the function of downregulation of OCT4 in the proliferation, cycle, tumorigenesis, and drug resistance of the SP of SKOV3 or A2780 cells. Figure 2A, B showed the knockdown efficiencies of shRNA-OCT4 in SP SKOV3 and SP A2780 cells and that the protein expression of OCT4 was downregulated apparently when the SP SKOV3 and A2780 cells were transfected with shRNA-OCT4. CCK-8 results showed that OCT4 downregulation significantly enhanced the drug sensibility of SP SKOV3 and SP A2780 cells (Figure 2C, D), as well as reduced cell proliferation ability (Figure 2E–F). The result of flow cytometry showed that knockdown of OCT4 induced G2/M phase arrest of the SP of A2780 and SKOV3 cells (Figure 2G, H). Moreover, knockdown of OCT4 significantly reduced the tumorigenesis (Figure 2I, J) of the SP cells. Overall, the above results revealed that downregulated OCT4 impaired the malignancy of SP cells in ovarian cancer.

Upregulation of OCT4 enhances the proliferation and drug resistance of the NSP of ovarian cancer cells

To further explore the function of OCT4 in ovarian cancer progression, we also investigated the effects of overexpression of OCT4 in the proliferation, cycle, and drug resistance of the NSP of SKOV3 or A2780 cells. Figure 3A, B showed that the expression of OCT4 protein in the NSP of SKOV3

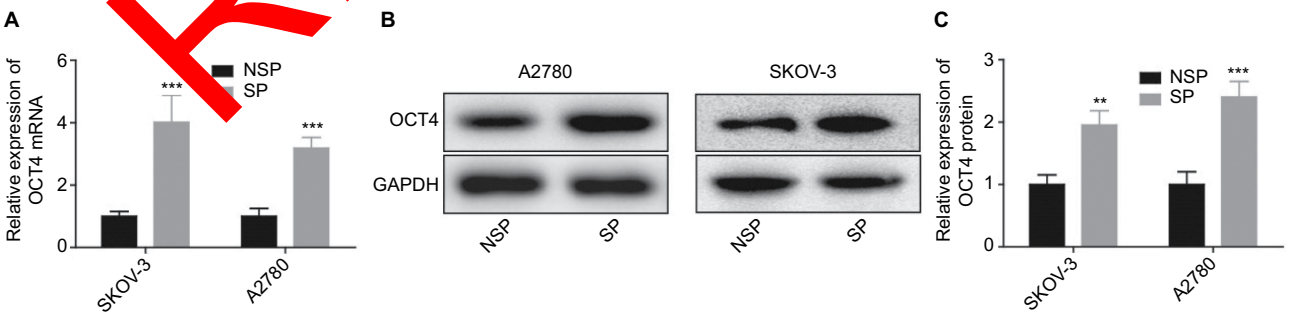

Figure 1 OCT4 was overexpressed in the SP of ovarian cancer cells.
Notes: (A–C) Western blotting and RT-PCR were carried out to analyze the protein and mRNA expressions of OCT4 in the SP and NSP population of SKOV3 and A2780 cells. ***P*< 0.01; ****P*<0.001.
Abbreviations: NSP, non-SP; SP, side population.

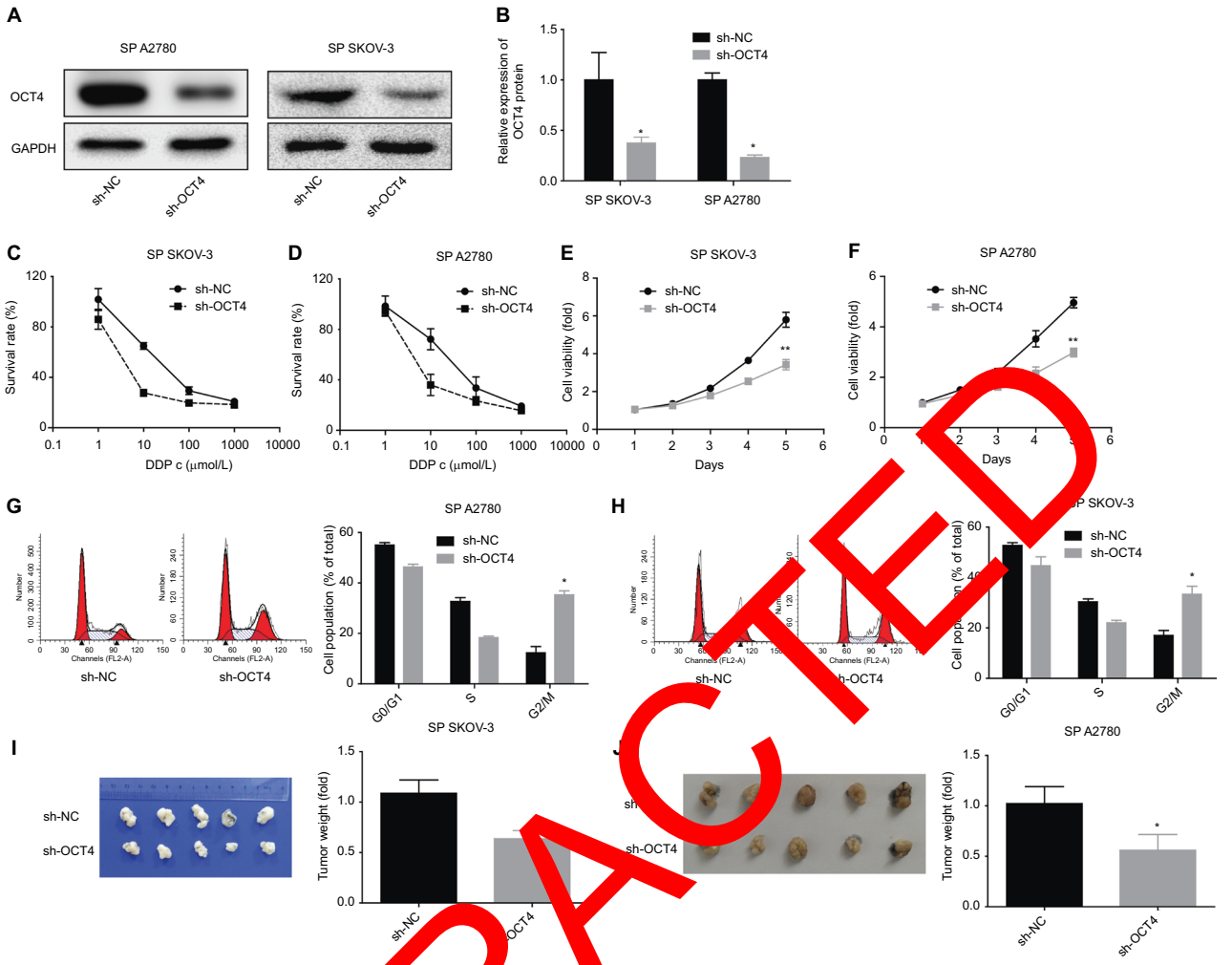

Figure 2 Downregulation of OCT4 reduced cell drug resistance and cell proliferation and tumorigenesis in the SP of ovarian cancer cells.
Notes: (**A**, **B**) Western blotting analysis of the knockdown efficiency of OCT4 after 48 hours of the cells were transfected with sh-OCT4. (**C**, **D**) Different concentrations of DDP were added in the SP of SKOV3 and A2780 cells after 48 hours of the cells were transfected with sh-OCT4, then CCK-8 assay was performed to assess cell viability. (**E**, **F**) CCK-8 analysis of cell viability after hours of cell treatments. (**G**, **H**) Flow cytometry analysis of cell cycle after 48 hours of cell treatments. (**I**, **J**) In vivo xenograft model was carried out to analyze the effect of shOCT4 on tumorigenesis in the SP cells. The data presented are the mean ± standard error and represent three independent experiments (*P<0.05; **P<0.01). Effects of downregulation of OCT4 on cell viability and cycle in the SP population of SKOV3 cells.
Abbreviations: CCK-8, cell counting kit-8; SP, side population.

and A2780 cells was obviously elevated when the cells were infected with Lentiv-OCT4 compared with the control group, OCT4 overexpression significantly reduced the drug sensitivity (Figure 3C, D) and promoted cell viability (Figure 3E, F) of the SP of SKOV3 and A2780 cells. In addition, upregulated OCT4 induced S-phase arrest in the NSP cells (Figure 3G, H). The above results confirmed that OCT4 upregulation conferred NSP cells with drug resistance and malignant phenotype in ovarian cancer.

OCT4 activates JAK/STAT signaling pathway in the NSP of ovarian cancer cells

To explore the underlying mechanism of OCT4 in the progression of ovarian cancer, we assessed the expressions of proteins related to JAK/STAT, PI3K/AKT, and NF-κB signaling pathways. Results showed that downregulation of OCT4 in the NSP SKOV3 and A2780 cells dramatically suppressed the phosphorylation of JAK1 and STAT6 but had no influence on the phosphorylated levels of AKT and NF-κB (Figure 4A, B). To further investigate the role of JAK/STAT signaling in OCT4-mediated ovarian cancer development, we also detected the effect of OCT4 on the phosphorylated levels of proteins of JAK family (JAK1, JAK2, JAK3, and Tyk2) and STAT family (STAT1/-2/-3/-4/-5/-6). As shown in Figure 4C, D, phosphorylated levels of JAK1, JAK2, JAK3, and Tyk2 were all elevated when treated with the NSP SKOV3 or A2780 cells with Lentiv-OCT4, with the phosphorylated level of JAK1 increased highest. Besides, the phosphorylated levels of STAT1/-2/-3/-4/-5/-6 were also elevated when treated

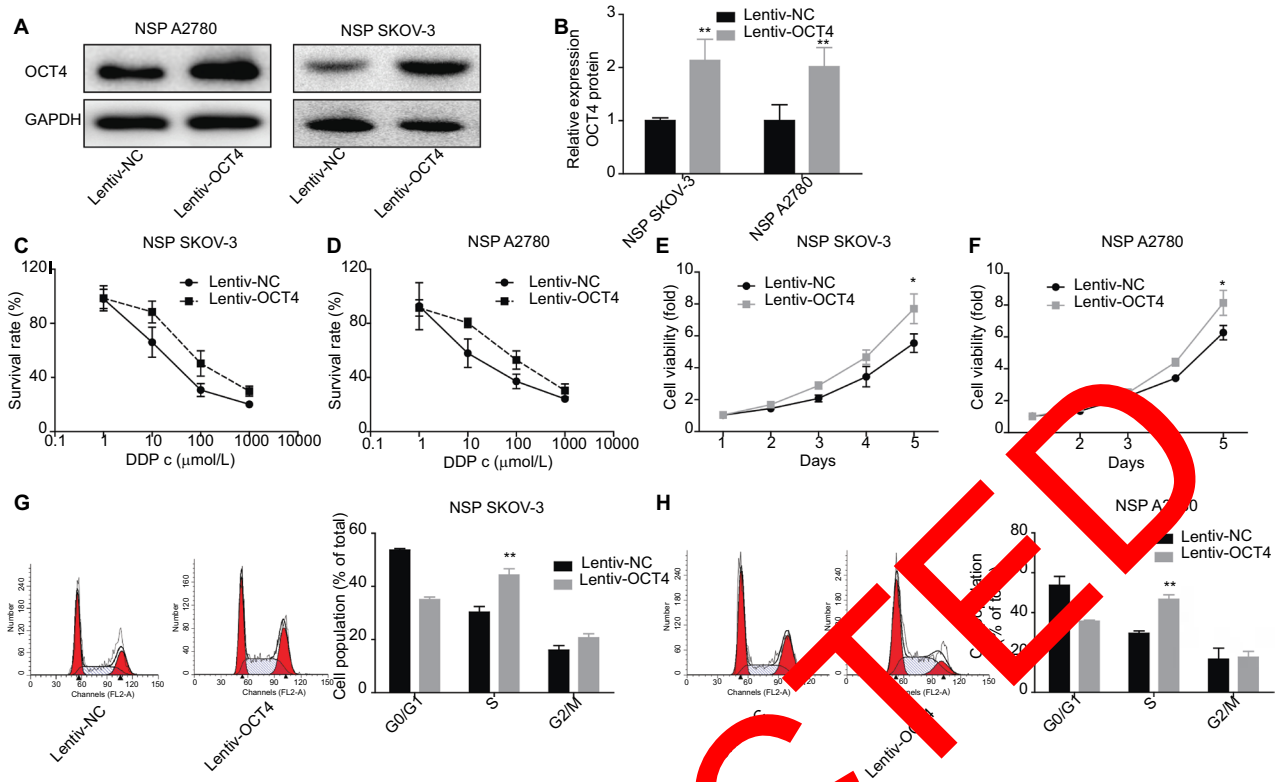

Figure 3 Effects of OCT4 overexpression on cell functions and drug resistance in the NSP of SKOV3 and A2780 cells.
Notes: (**A**, **B**) Western blotting was carried out to analyze the protein expressions of OCT4 after 48 hours of the SP cells were treated with Lentiv-OCT4 or Lentiv-NC, respectively. (**C**, **D**) Different concentrations of DDP were added in the NSP of SKOV3 and A2780 after 48 hours of the cells were treated with Lentiv-OCT4 or Lentiv-NC, and then CCK-8 assay was performed to assess cell viability. (**E**, **F**) CCK-8 assay of cell proliferation after 48 hours of the NSP cells was infected with Lentiv-OCT4 or Lentiv-NC. (**G**, **H**) Flow cytometry was used to assess cell cycle after 48 hours of the NSP cells were infected with Lentiv-OCT4 or Lentiv-NC. The data presented are the mean ± standard error and represent three independent experiments (*$P<0.05$, **$P<0.01$).
Abbreviations: CCK-8, cell counting kit-8; NSP, non-SP; SP, side population.

with the NSP cells with Lentiv-OCT especially STAT6 (Figure 4E, F). According to this, we performed immunofluorescence staining to determine the subcellular location of STAT6 in the presence of Lentiv-OCT4. Results showed that overexpression of OCT translocates STAT6 from cytoplasm to nuclear in the NSP cells (Figure 4G, H). Moreover, the protein expression levels of Cyclin D1, c-Myc, and Bcl-2 were all increased when the NSP cells were infected with Lentiv-OCT4 (Figure 4I, J). Together, these results showed that OCT4 promoted ovarian cancer development through activation of JAK/STAT signaling pathway.

OCT4 accelerates ovarian cancer progress through activation of JAK/STAT signaling pathway

Finally, we evaluate the role of JAK/STAT signaling in the OCT4-induced oncogenes in ovarian cancer NSP SKOV3 or A2780 cells. Peficitinib, an inhibitor of JAK, was used to repress the activation of JAK/STAT signaling. OCT4 upregulation decreased the expression of caspase-3 and inhibited cell apoptosis, but this effect was abolished when adding peficitinib in both the NSP of SKOV3 and A2780 cells (Figure 5A–D). Furthermore, CCK-8, clone formation, and Transwell assays were carried out to evaluate the effects of OCT4/JAK/STAT on the drug resistance and invasion of the NSP cells, and results showed that the promotion of drug resistance (Figure 5E), clone formation (Figure 5F), and invasion abilities (Figure 5G–H) induced by OCT4 upregulation was neutralized when adding peficitinib in the NSP SKOV3 and A2780 cells. Besides, upregulation of OCT4 promoted the tumorigenesis of the SP SKOV3 and A2780 cells, and this effect was impaired when adding peficitinib (Figure 6). All results suggested that OCT4 promoted ovarian cancer progress through activation of JAK/STAT signaling pathway.

Discussion

Ovarian cancer has been reported to have the highest mortality rate among all female reproductive system cancers.[22] High

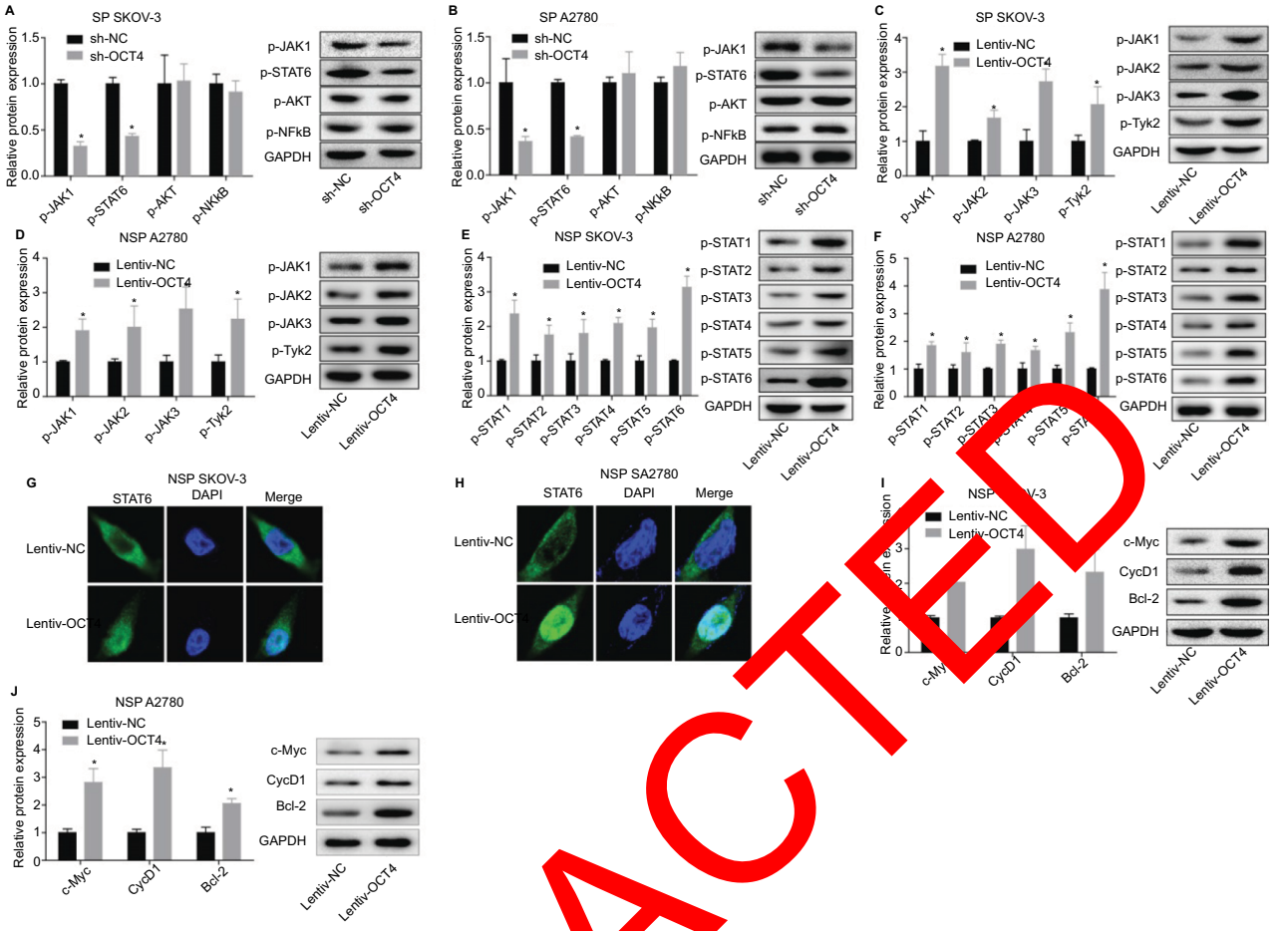

Figure 4 Evaluation of the effect of OCT4 on JAK/STAT signaling pathway activation in the NSP of SKOV3 and A2780 cells.

Notes: (**A**, **B**) Western blotting analysis of the protein expressions of phosphorylated JAK1 (p-JAK1), p-STAT6, p-AKT, and p-NF-κB after 48 hours of the NSP cells was infected with Lentiv-OCT4 or Lentiv-NC. (**C**, **D**) Western blotting analysis of the protein expressions of p-JAK1, p-JAK2, p-JAK3, and p-Tyk2 after 48 hours of the NSP cells was infected with Lentiv-OCT4 or Lentiv-NC. (**E**, **F**) Western blotting analysis of the protein expressions of p-STAT1, p-STAT2, p-STAT3, p-STAT4, p-STAT5, and p-STAT6 after 48 hours of the NSP cells was treated with Lentiv-OCT4 or Lentiv-NC. (**G**, **H**) Immunofluorescence staining was used to determine the subcellular location of STAT6 after 48 hours of the SP SKOV3 cells were transfected with Lentiv-OCT4. (**I**, **J**) Western blotting analysis of the expression of Cyclin D1, c-Myc, and Bcl-2 after 48 hours of the NSP cells was treated with Lentiv-OCT4 or Lentiv-NC. The data presented are the mean ± standard error and represent three independent experiments (*,#$P<0.05$).

Abbreviation: NSP, nonside population.

mortality is attributed to late diagnosis of the disease and ineffectiveness of chemotherapy. Accumulated evidence has suggested that the existence of CSCs might account for the resistance of ovarian cancer to conventional chemotherapy or radiation therapy.[24] Therefore, agents capable of vanishing CSC population are imperative for improving the clinical outcomes of ovarian cancer patients. And this study illustrated that OCT4 was highly expressed in SP population of the ovarian cancer cell lines SKOV3 and A2780 compared with the NSP population. Upregulation of OCT4 accelerated the progression of ovarian through activating JAK/STAT signaling with respect to promotion of the viability, invasion, and tumorigenesis and induction of drug resistance of the SP in ovarian cancer cells.

SP cells are enriched with CSCs in a variety of carcinomas.[25–28] These cells have been isolated from malignancies, including ovarian cancer.[29] In general, SP has been served as a practical method to enrich and isolate CSCs from many tumor tissues and cell lines.[30] Hu et al[31] demonstrated that SP population separated from overall cancer cells indeed have the properties of CSCs. And in this study, we found that the SP population of ovarian cancer SKOV3 and A2780 cells highly expressed the ESCs marker, OCT4, compared with that in the NSP cells, which was consistent with the previous study.[31] OCT4 is reported to be more significantly overexpressed in poorly differentiated tumors than in well-differentiated tumors.[32] OCT4 is a well-documented marker for CSC in ovarian cancer, and it plays key roles in tumor cell growth, survival, metastasis, and chemoresistance in vitro and in vivo models of ovarian cancer.[20] Similarly, in this study, we demonstrated that downregulation of OCT4 alleviated the chemoresistance to DDP of the SKOV3 and

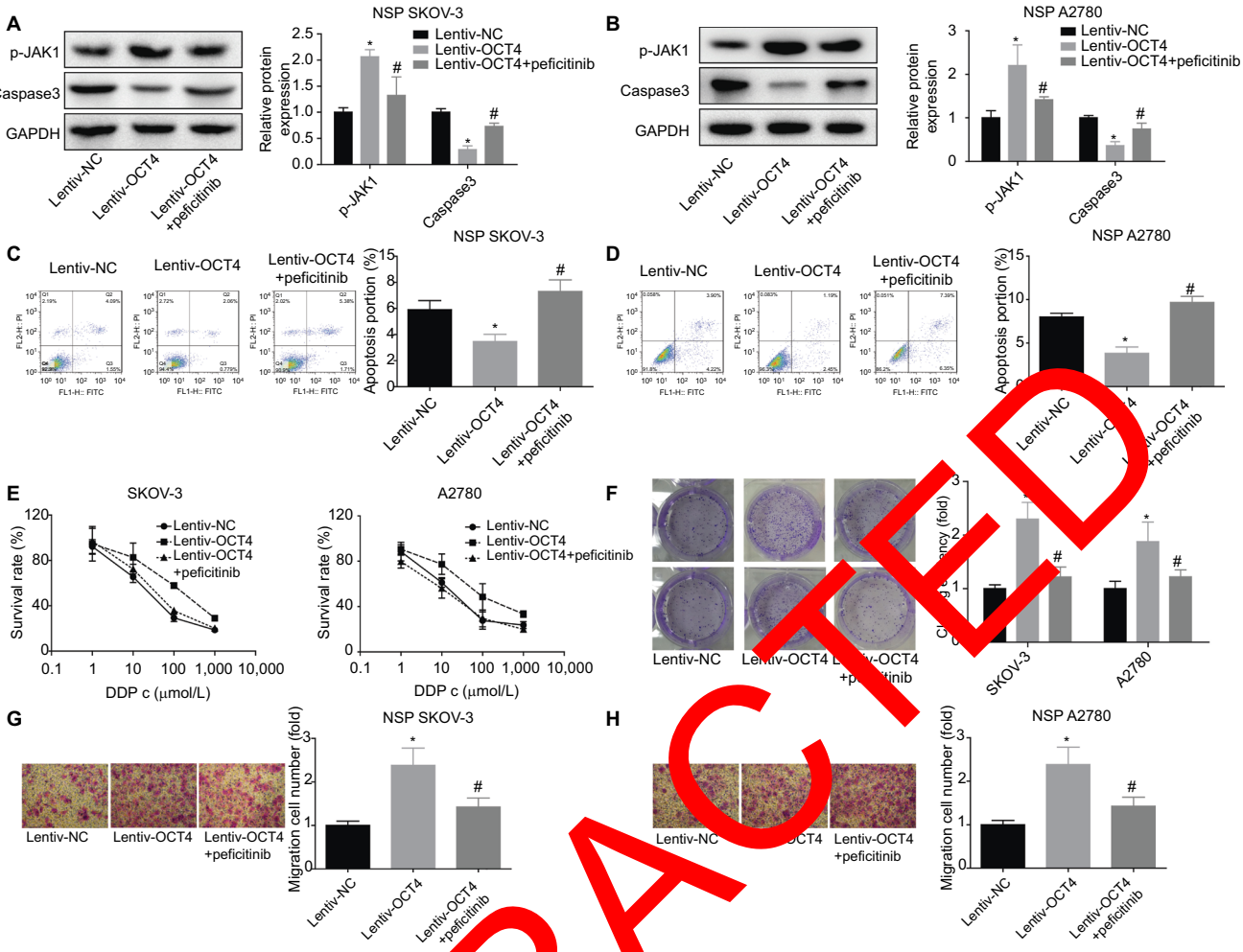

Figure 5 Assessment of the effects of OCT4/JAK/STAT on [illegible] function [illegible] NSP of SKOV3 and A2780 cells.
Notes: (**A, B**) Western blotting analysis of the protein levels of JAK and caspase-3 in different treated NSP cells: Lentiv-NC (48 hours), Lentiv-OCT4 (48 hours), and peficitinib (4.8 nM, 2 hours) + Lentiv-OCT4 (48 hours). (**C, D**) Flow cytometry was performed to assess the apoptosis of the NSP cells with different treatments: Lentiv-NC (48 hours), Lentiv-OCT4 (48 hours), and peficitinib (4.8 nM, 2 hours) + Lentiv-OCT4 (48 hours). (**E, F**) CCK-8 and clone formation assays were performed to assess cell viability in the SP cells with different treatments: Lentiv-NC (48 hours), Lentiv-OCT4 (48 hours), and peficitinib (4.8 nM, 2 hours) + Lentiv-OCT4 (48 hours). (**G, H**). Transwell assay was used to evaluate the invasion of the NSP cells with different treatments: Lentiv-NC (48 hours), Lentiv-OCT4 (48 hours), and peficitinib (4.8 nM, 2 hours) + Lentiv-OCT4 (48 hours). The data presented are the mean ± standard error and represent three independent experiments (*,#$P<0.05$).
Abbreviations: CCK-8, cell counting kit-8; NSP, nonside population.

A2780 SP cells. Besides, inhibition of proliferation and tumorigenesis and arrest of a G2/M phase were induced by OCT4 downregulation in the SP cells.

We also observed that overexpression of OCT4 increased the phosphorylated activation of JAK1-3 and Tyk2 and STAT1-6 and accelerated the translocation of STAT6 from cytoplasm to nuclear, suggesting that OCT4 upregulation activated JAK/STAT signaling. In the canonical pathway, JAK/STAT signaling becomes active upon binding of an extracellular ligand to a transmembrane receptor, eventually, STAT dimerizes are phosphorylated and move to the nucleus to modulate the transcription activities of its downstream target genes.[33] JAK/STAT signaling pathway plays a vital role not only in the transformation of stationary epithelial cells to invasive cells,[34,35] and cell migration,[36–38] but also in maintenance of stem cell self-renewal. For example, Flaherty et al[39] found that chinmo is a functional effector of the JAK/STAT pathway that regulates eye development, tumor formation, and stem cell self-renewal in *Drosophila*. Inhibition of the JAK-STAT represses tumor initiation and clonogenic recovery of prostate CSCs.[40] Besides, Kim et al[41] suggested that the IL-6/JAK1/STAT3 signal transduction pathway plays an important role in the conversion of non-CSCs into CSCs through regulation of OCT4 gene expression. In ovarian cancer, study demonstrated that inhibition of the JAK2/STAT3 pathway by the addition of CYT387 suppressed the stemness profile in chemotherapy-

treated residual ovarian cancer cells.[12] And our results were consistent with these studies, in which we indicated that inhibition of SIRT/STAT signaling with peficitinib significantly destroyed the roles of OCT4 upregulation in cell proliferation, invasion, and tumorigenesis promotion and cell apoptosis repression in NSP SKOV3 and A2780 cells.

Conclusion

Our study demonstrated that OCT4 was highly expressed in the SP population of SKOV3 and A2780 ovarian cancer cells. Downregulation of OCT4 distinctly decreased the viability, tumorigenesis, and drug resistance of SP cells, and OCT4 upregulation endowed the NSP of ovarian cancer cells malignant features. Moreover, we also revealed that JAK/STAT signaling inhibition alleviated the tumor-feeding effects caused by the upregulation of OCT4 in NSP cells (Figure 7). Overall, our study suggested that OCT4/JAK/STAT should be served as a potent target for ovarian cancer treatment.

Acknowledgment

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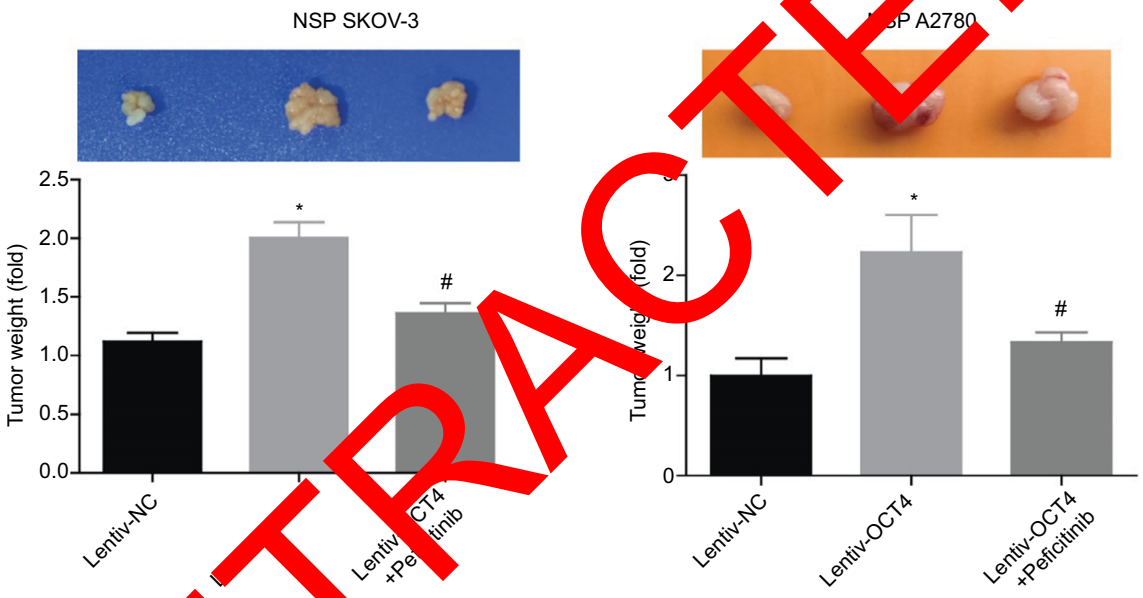

Figure 6 Detection of the eff[illegible] of OCT4/JAK/STAT on [illegible] tumorigenesis of the NSP of SKOV3 and A2780 cells.
Notes: In vivo xenograft [illegible]del analysis [illegible]f the effect of OCT4/JAK/STAT on tumorigenesis. The data presented are the mean ± standard error and represent three independent experiments ([illegible]P<0.05).
Abbreviation: NSP, nonside[illegible]ulation.

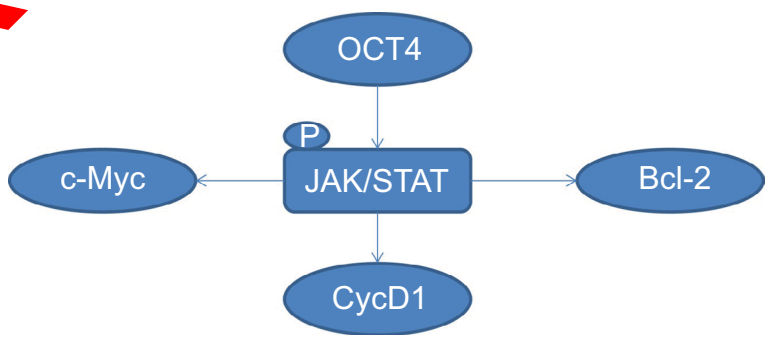

Figure 7 Graphical abstract of this study.
Notes: OCT4 activates JAK/STAT signaling, then promotes the expression of Cyclin D1, c-Myc, and Bcl-2, accelerating the tumorigenesis of NSP cells in ovarian cancer.
Abbreviation: NSP, nonside population.

Disclosure

The authors report no conflicts of interest in this work.

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