OncoTargets and Therapy

Dovepress
open access to scientific and medical research

Open Access Full Text Article

ORIGINAL RESEARCH

RETRACTED ARTICLE: MicroRNA-217 acts as a tumor suppressor and correlates with the chemoresistance of cervical carcinoma to cisplatin

This article was published in the following Dove Medical Press journal:
OncoTargets and Therapy

Zhaojun Yin
Weiru Ren

Gynaecology Ward of Maternal and Child Health Hospital, Shizhong District, Zaozhuang 277100, Shandong, People's Republic of China

Background: MicroRNA-217 (miR-217) has been demonstrated to participate in the tumorigenesis and progression of various types of cancers. Nevertheless, the role of miR-217 in cervical carcinoma still remains not fully elucidated. This current work sought to investigate the role of miR-217 in the growth, migration, and invasion of cervical carcinoma and detect the role of miR-217 in the chemosensitivity of cervical carcinoma cell to cisplatin.

Materials and methods: The levels of miR-217 in 65 pairs of cervical carcinoma tissues and matched normal tissues were detected using quantitative real-time-PCR assay. The roles of miR-217 on the growth, apoptosis, migration, and invasion of cervical cancer SiHa and Ca-Ski cells were analyzed using Cell Counting Kit-8, flow cytometry, wound healing, and Transwell invasion assays, respectively. The target of miR-217 was identified using the online analysis tool TargetScan (http://www.targetscan.org/vert_72/) and was verified by luciferase reporter and immunoblotting assay. The xenograft tumor model was constructed to explore the impact of miR-217 on the growth of cervical carcinoma cell in vivo.

Results: The level of miR-217 was remarkably lower in cervical carcinoma tissues than that in noncancerous tissues. Overregulation of miR-217 markedly suppressed the aggressiveness of cervical cancer cell and induced cell apoptosis through regulating V-Ki-Ras2 Kirsten rat sarcoma viral oncogene homolog (KRAS). Finally, upregulation of miR-217 enhanced the chemosensitivity of both SiHa and Ca-Ski cervical cancer cells toward cisplatin.

Conclusion: Altogether, upregulation of miR-217 inhibits the aggressiveness phenotypes of cervical carcinoma cell via regulating *KRAS* gene and increases the sensitivity of cervical cancer cell to cisplatin.

Keywords: cervical cancer, cisplatin, miR-217, KRAS

Introduction

Cervical carcinoma is one of the main causes of cancer-associated death in women worldwide.[1,2] The alterations in multitudinous tumor suppressor genes and oncogenes have been identified in cervical carcinoma.[3] MicroRNAs (miRNAs), which belong to a family of small RNA, regulate both the degradation and translation of target gene.[4] miRNAs bind to the 3′-UTR of target gene and further participate in translational repression or mRNA degradation.[5] Substantial investigations confirm that miRNAs participate in various biological processes, including cell proliferation, cell cycle, glucose metabolism, lipid metabolism, signaling intermediates, and response to external stimulants.[6]

Recently, miRNAs have been proved to play core roles in numerous cellular processes during tumor progression, such as cancer cell growth, apoptosis, and metastasis.[7] miRNAs function as anti-oncogene or oncogene and participate in tumorigenesis via

Correspondence: Weiru Ren
Gynaecology Ward of Maternal and Child Health Hospital, No 25 Cultural East Road, Shizhong District, Zaozhuang 277100, Shandong, People's Republic of China
Email weiruluck@163.com

submit your manuscript | www.dovepress.com
Dovepress
http://dx.doi.org/10.2147/OTT.S176618

regulating their targets.[8] In cancer metastasis progression, miRNAs regulate cancer cell migration and invasion through directly targeting cancer suppressors or oncogenes.[9] For example, *miR-17-92*, *miR-21*, and *miR-31* act as oncogenes.[10] However, miR-451, miR-15/16, let-7, miR-125a/125b, and miR-145 act as suppressive miRNAs.[11,12] Simultaneously, specific miRNAs act as tumor suppressors or oncogenes depending on the cancer type. For instance, miR-96 inhibits the levels of FOXO1 in breast cancer and is associated with the survival of patients with breast carcinoma.[13] Alternatively, miR-96 plays inhibitory roles in pancreatic carcinoma through regulating Kirsten rat sarcoma viral oncogene homolog (KRAS).[14] Similarly, miR-217 directly targets V-Ki-Ras2 KRAS or Sirtuin 1 (SirT1) in human pancreatic ductal adenocarcinoma, whereas it targets phosphatase and tensin homolog (*PTEN*) (a tumor suppressor gene) in renal carcinoma.[15] In breast cancer, miR-217 is commonly overregulated and enhances tumor proliferation via promoting cell cycle progression by targeting Dachshund Family transcription factor 1.[16] Nevertheless, the potential functions of miR-217 in cervical carcinoma have not been investigated.

miRNAs dysregulation contributes to the cisplatin chemoresistance in cancer and the correlation between miRNA alternation and chemoresistance has attracted increasing attentions.[17] In non-small-cell carcinoma, miRNA-217 upregulates the sensitivity of cancer cell to cisplatin.[18] In addition, downregulation of miR-217 is associated with the resistance of ph^+ leukemia cells to V-Abl Abelson Murine Leukemia Viral (ABL) tyrosine kinase inhibitors. However, the relationship of miRNA-217 with the chemotherapy resistant cervical carcinoma cell has not been fully investigated.

In this study, we found that miR-217 was downregulated in cervical carcinoma, and upregulation of miR-217 reduced the resistance of cervical cancer cell toward cisplatin. Furthermore, overregulation of miR-217 significantly inhibited the proliferating, migration, and invasion of cervical carcinoma cell in vitro as well as the tumor growth of cervical carcinoma cell in vivo. The results of dual-luciferase reporter and Western blotting assays demonstrated that miR-217 directly targets and inhibits the expression of *KRAS* gene. Altogether, these findings provide a basis for the role of miR-217 in the aggressiveness of cervical carcinoma and the chemoresistance of cervical carcinoma to cisplatin.

Materials and methods

Cell lines

The cervical carcinoma cells (SiHa and Ca-Ski) and normal cervical epithelial cells (ECT1/E6E7) were purchase from the Cell Bank of Type Culture Collection of Chinese Academy of Sciences (Shanghai, People's Republic of China). Cells were cultured in RPMI 1640 (Thermo Fisher Scientific, Waltham, MA, USA) supplemented with 10% FBS (Wisent Bioproducts, Saint-Jean-Baptiste, QC, Canada), 100 µg/mL penicillin, and 100 µg/mL streptomycin. ECT1/E6E7 cells were cultured in DMEM (Thermo Fisher Scientific) supplemented with 10% FBS (Wisent Bioproducts), 100 µg/mL penicillin, and 100 µg/mL streptomycin. All cells were maintained in an incubator with a humidified atmosphere of 95% air and 5% CO_2 at 37°C.

Cervical cancer tissues

Sixty-five pairs of cervical carcinoma and matched noncancerous tissues were obtained from Gynecology ward of Maternal and Child Health Hospital during 2006–2017. The study was approved by the Research Ethics Committee of Gynaecology Ward of Maternal and Child Health Hospital (Zaozhuang, Shandong, People's Republic of China). The enrollment criteria were cervical carcinoma patients with no preoperative radiotherapy or chemotherapy and with clinical follow-up data. Clinical stage was determined according to the International Federation of Obstetrics and Gynaecology, 2009. All tissues were used according to the ethical guidelines of the 1975 Declaration of Helsinki and obtained with the patients' understanding that it might be published. The written informed consent for participation in the study was obtained from all patients before participation in this study. The clinical information of patients has been summarized in Table S1.

miRNA transfections

miR-217 mimics, scramble mimics, anti-miR-NC (negative control), and anti-miR-217 were synthesized by GenePharma (Shanghai, People's Republic of China). miRNAs (10 nM) were transfected into cervical cancer cell using DharmaFECT1 Reagent (Dharmacon, Lafayette, CO, USA). To construct stably overexpressing miR-217 SiHa cell, lentiviral constructs (Lenti-miR™ miRNA precursor clones; System Biosciences, Palo Alto, CA, USA) expressing miR-217 or respective empty vector (miR-NC) were packaged using the pPACKH1 Lentivector Packaging System (System Biosciences) and were used to transfect into SiHa cell. Stable clones were selected using 1 µg/mL puromycin (Thermo Fisher Scientific).[20,21]

Quantitative real-time (qRT)-PCR analysis

Total RNA was isolated using Trizol reagent (Thermo Fisher Scientific) and the first strand cDNA was synthesized with 1 µg total RNA using a PrimeScript RT reagent kit (Takara

Bio Inc., Shiga, Japan). qRT-PCR was conducted using iQ™ SYBR® Green Supermix and the iQ5 real-time detection system (Bio-Rad Laboratories Inc., Hercules, CA, USA). The comparative cycle threshold (Ct) method was applied to quantify the expression levels by calculating the $2^{(-\Delta\Delta Ct)}$ method. For mRNA detection, GAPDH was internal control.[22] In miRNA analysis, U6 was selected for control. The specific primers used were as follows: KRAS sense, 5′-TGTGTCT CATATCAGGTTGACGA-3TGTCTCATATCAGGTT5′-CAAGAGTCGAGTGTGGTCTCA-3AGAGTCGAGTG TGGTCTCAGAsed were as follTCA-3′, and antisense 5′-GT CATGATGGCAACAATATCCACT-3′; U6 sense, 5′-AAA GTGGCTAAACGAAGCTGAA-3′, and antisense 5′-GTG GGCAGTGGGTTCTTCTC-3′.[23] For detecting miR-217, the mirVana™ miRNA Isolation Kit (Thermo Fisher Scientific) was used to isolate total RNA from cell lines and patient tissues following the manufacturer's instructions. miR-217 was detected using Platinum Taq DNA Polymerase (Thermo Fisher Scientific) with specific primers: sense, 5′-TACTC AACTCACTACTGCATC AGGA-3′, and antisense 5′-TAT GGT TGTTCTGCTCTCTGTGTC-3′.

Growth and apoptosis analysis

Cellular growth analysis was conducted using Cell Co[illegible] Kit-8 (CCK-8) (DOJINDO Molecular Technolo[illegible]es, Kumamoto, Japan). A total of 5,000 cells w[illegible]tured i[illegible] 96-well plate and the proliferation rat[illegible] were d[illegible]tected [illegible] 1 day, 2 days, 3 days, and 4 days by add[illegible] CC[illegible] (10 µL) into the plates. The apopt[illegible]s analys[illegible] was assayed in SiHa and Ca-Ski cells using t[illegible] a[illegible]ptosis dete[illegible]on kit (BD Biosciences, San Jose, CA, USA) o[illegible]e C6 flow cytometer (BD Biosciences).

Migration assay

Wound he[illegible]ng a[illegible]ay wa[illegible]ond[illegible]cted to analyze cell migration. Th[illegible] gaps we[illegible] made on [illegible]e cell monolayer using 100 µL pipette t[illegible] Th[illegible] images [illegible]ere taken at 0 hour and 24 hours after gaps w[illegible] generated.

Invasion assay

In the invasion assay, the upper chambers of the Transwell inserts were coated with 50 µL of 2.0 mg/mL Matrigel (BD Biosciences). Cells (5×10^4) were suspended in 200 µL FBS free medium and added into the upper chamber. A total of 600 µL culture medium containing 20% FBS was put into lower chamber. After 24 hours, the invaded cells were stained with 1% crystal violet and counted in five random fields.

Animal experiment and immunohistochemistry

A total of 100 µL miR-NC or stably overexpressing miR-217 SiHa cells (6×10^6) were inoculated s.c. into BALB/c nude mice. The tumor volume was assayed for 6 weeks. Then, the tumor mass was resected and tumor weight was recorded. The animal experiment was approved by the institutional ethical guidelines for animal experiments from Gynaecology Ward of Maternal and Child Health Hospital (Zaozhuang, Shandong, People's Republic of China) and was performed in accordance with Institutional Gui[illegible]s and the Guide for the Care and Use of Laborato[illegible] Animals ([illegible]IH publication no 85-23, revised 1996). Tum[illegible] tissues wer[illegible] subjected for immunohistochemical ([illegible]H) stai[illegible]g assay.

Luciferase repo[illegible]rte[illegible] analysis

Mutations of [illegible]e predicte[illegible]3′-UTR [illegible] KRAS were made using primers c[illegible]ta[illegible]ing mutated [illegible]. The 3′-UTRs of KRAS were PCR-amplified a[illegible] inserted into pMIR-REPORT™ miRNA re[illegible]te[illegible]vector (Therm[illegible]Fisher Scientific). HEK-293T cells were [illegible]ansfected with pMIR-REPORT™ and miR-217 or miR-NC [illegible]sing Lipofec[illegible]mine® 2000 reagent (Thermo Fisher Scientific). L[illegible]iferase ac[illegible]ity was detected under the guidance of Luciferase Reporter Assay (Promega Corporation, Fitchburg, WI, USA).

Immunoblotting

Total proteins were abstracted from cells and were separated on 8% SDS-PAGE, and then transferred onto polyvinylidene fluoride (PVDF) membranes. Next, membranes were blocked using 5% nonfat dried milk and then incubated with KRAS antibody (1:1,000; Cell Signaling Technology, Inc., Danvers, MA, USA) for 2 hours and GAPDH antibody (1:1,000; Proteintech Group, Inc., Rosemont, IL, USA). After being washed with Tris Buffered Saline Tween (TBST), PVDF membranes were incubated with goat anti-rabbit secondary antibody (1:5,000; Zhongshanjinqiao, Beijing, People's Republic of China) for 2 hours. The signal bands were assessed using the enhanced chemiluminescence (ECL) detection reagent (Thermo Fisher Scientific).

Statistics

Statistical analyses are performed using SPSS 14.0 (SPSS Inc., Chicago, IL, USA). All experiments were independently repeated at least three times. All data are presented as the mean ± SD. Differences in the results of the two groups were evaluated using either two-tailed Student's *t*-test or one-way ANOVA followed by post hoc Dunnett's test. Overall survival curves were estimated using the Kaplan–Meier method. $P<0.05$ is considered statistically significant.

Results

miR-217 is downregulated in cervical cancer

The levels of miR-217 in 65 pairs of cervical cancer tissues and corresponding normal tissues were determined by qRT-PCR method. The representative H&E staining image of cervical cancer tissue and corresponding normal tissue is shown in Figure S1. As shown in Figure 1A, miR-217 was downregulated in cervical carcinoma tissues. Quantitative analysis suggested that the levels of miR-217 in stage I–II primary tumors were remarkably higher than that in stage III (Figure 1B). Importantly, lower level of miR-217 was associated with the shorter overall survival of patients with cervical carcinoma (Figure 1C). Finally, qRT-PCR analyses uncovered that miR-217 was remarkably downregulated in cervical carcinoma cells compared to ECT1/E6E7 cells (Figure 1D). Collectively, these findings suggest that the miR-217 is downregulated and is correlated in the progression of cervical carcinoma.

Upregulation of miR-217 suppresses the growth of cervical cancer cell

In order to investigate the role of miR-217 in the growth of cervical cancer cell, Ca-Ski and SiHa were transfected with miR-217 mimics to increase the level of miR-217. The level of miR-217 in both Ca-Ski and SiHa was detected by qRT-PCR assay (Figure S2). Then, CCK-8 growth tests were conducted to detect the impact of miR-217 on the proliferation

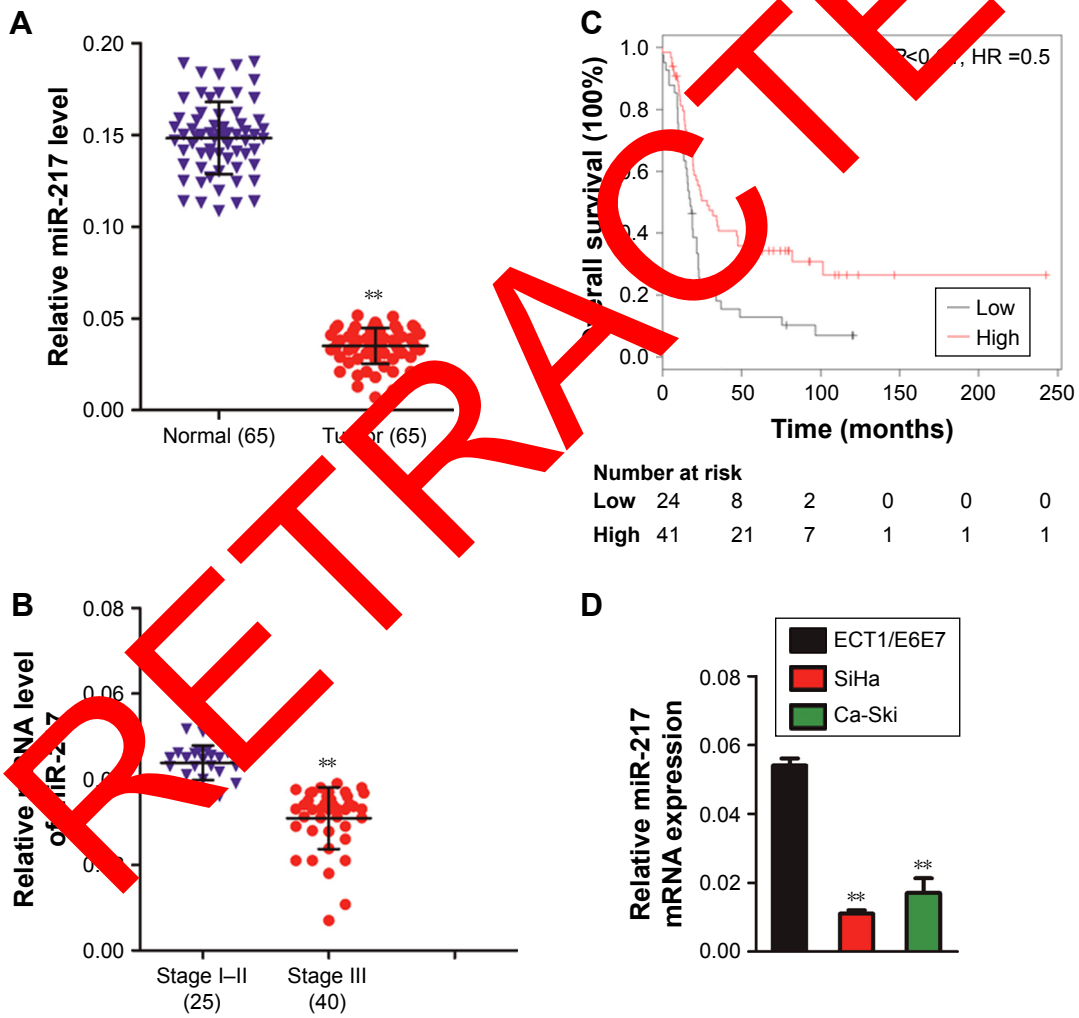

Figure 1 miR-217 is downregulated in cervical cancer.

Notes: (**A**) The level of miR-217 was assessed by qRT-PCR in 65 pairs of cervical carcinoma tissues as compared to the adjacent non-cancer tissues. $^{**}P<0.01$ compared to normal. (**B**) The level of miR-217 between different clinical stages of cervical cancer was statistically quantified. $^{**}P<0.01$ as compared to I–II stage. (**C**) The Kaplan–Meier survival analysis of cervical cancer patients with low or high level of miR-217. (**D**) qRT-PCR analysis of miR-217 in ECT1/E6E7 and two cervical cancer cell lines, U6 was used as a loading control. $^{**}P<0.01$ compared to ECT1/E6E7 cells.

Abbreviations: miR-217, microRNA-217; qRT, quantitative real-time.

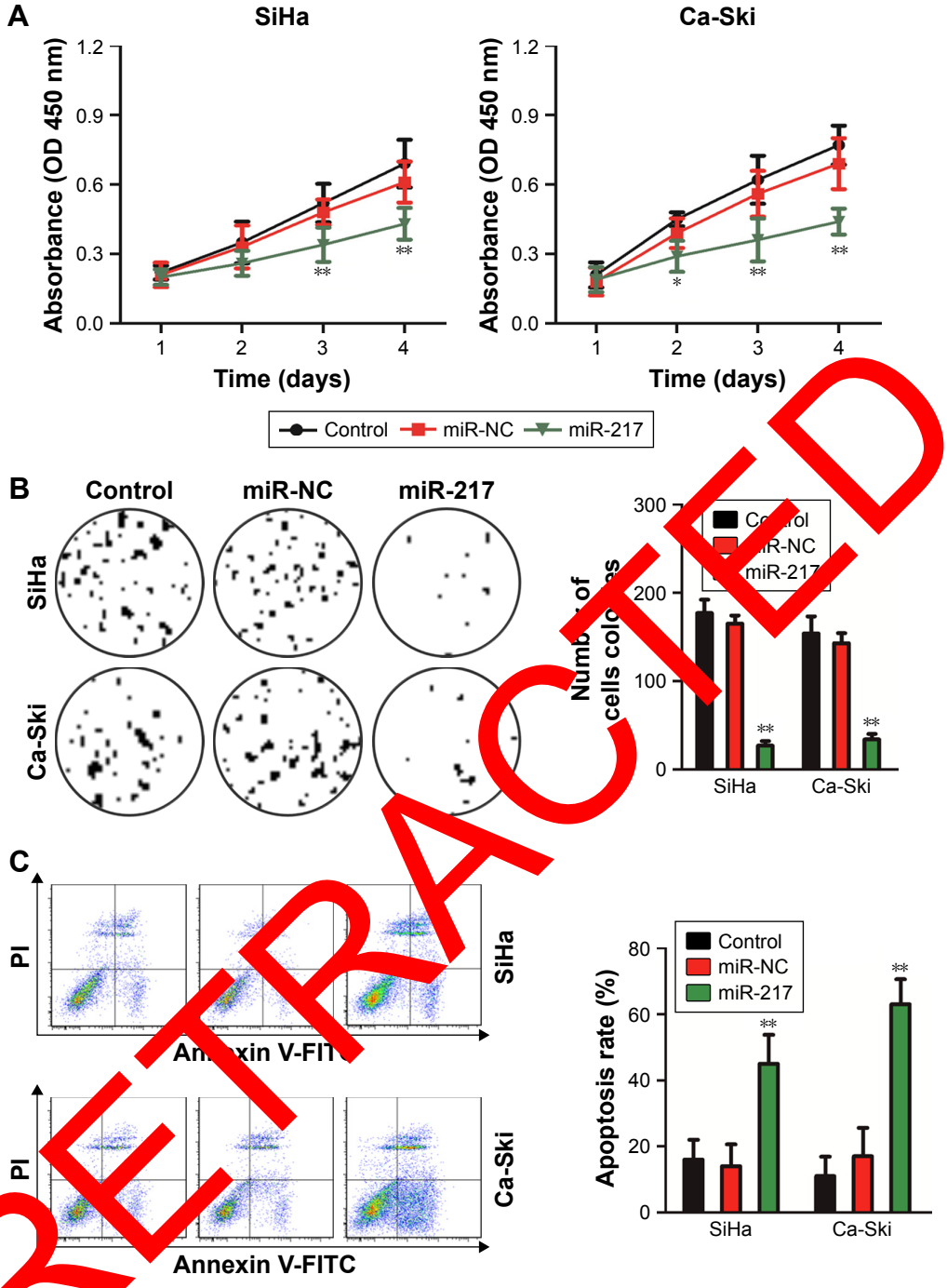

Figure 2 Overexpression of miR-217 suppresses cervical carcinoma cell growth and induces apoptosis.
Notes: (**A**) Upregulation of miR-217 inhibited the growth of SiHa and Ca-Ski. The growth index was assessed after 1, 2, 3, and 4 days. (**B**) Colony formation assay showed that miR-217 transfection reduced colony formation of both SiHa and Ca-Ski cells. (**C**) Overregulation of miR-217 increased the apoptosis of SiHa and Ca-Ski. Data are presented as mean ± SD, $^{*}P<0.05$ and $^{**}P<0.01$ compared to control.
Abbreviations: miR-217, microRNA-217; miR-NC, microRNA negative control.

of cervical carcinoma cell. As shown in Figure 2A, miR-217 transfection remarkably inhibited the growth of both Ca-Ski and SiHa cervical cancer cells as compared to scramble transfection. Consistently, apoptosis analysis demonstrated that overregulation of miR-217 induced the apoptosis of Ca-Ski and SiHa cells when compared to scramble transfection cell (Figure 2B). Nevertheless, the expressions of human papillomavirus (HPV) E6 or HPV E7 were not inhibited in miR-217-transfected cervical carcinoma cell as demonstrated by Western blotting assays (Figure S3). Altogether, these

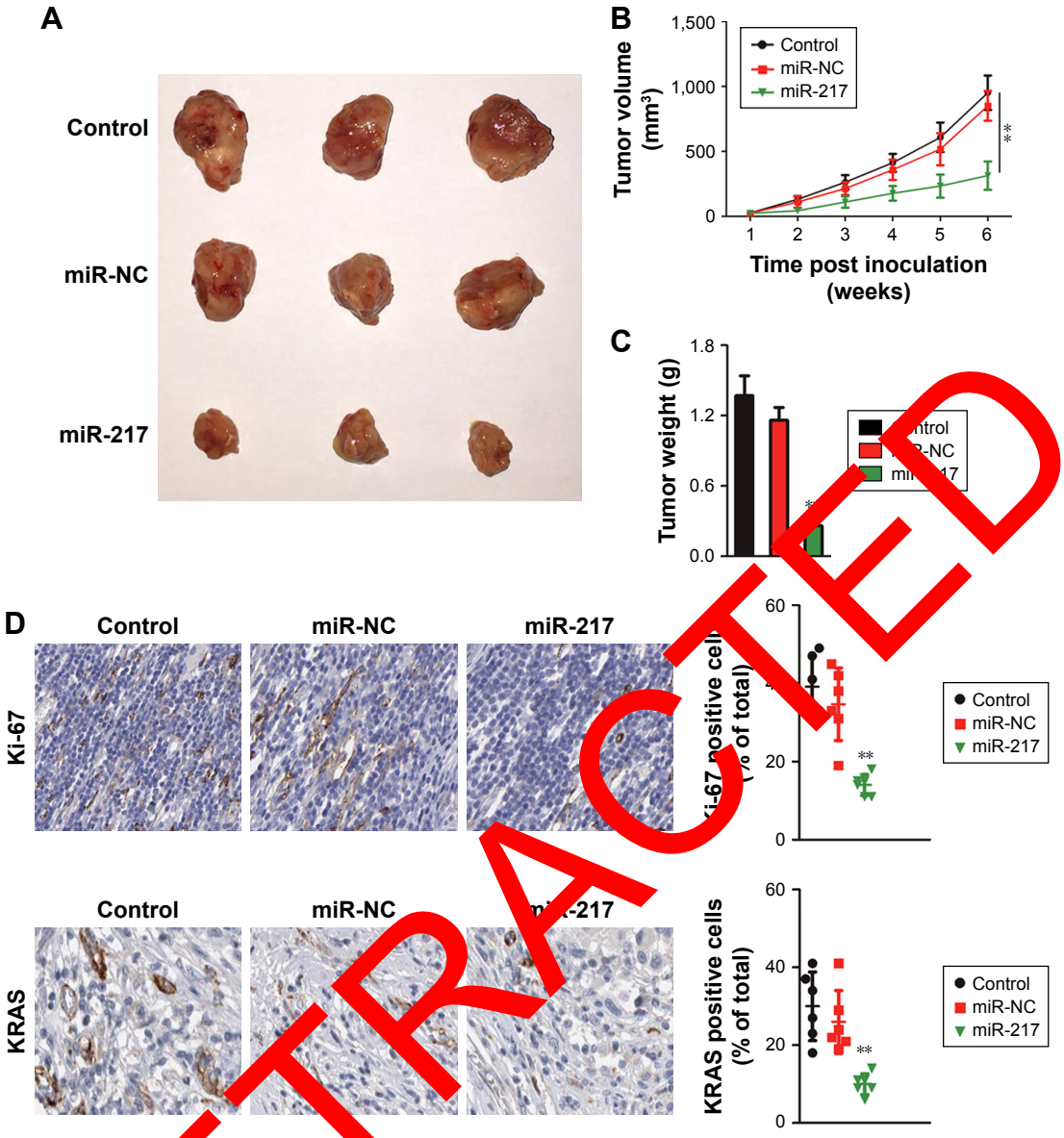

Figure 3 Overregulation of miR-217 inhibits tumor growth of cervical carcinoma cell in xenograft model.
Notes: (**A**) Parental or miR-217 overexpressing SiHa cells were subcutaneously inoculated into nude mice. The image represents tumor growth at 6 weeks after inoculation. (**B**) Tumor volume was measured. (**C**) Tumor weight was remarkably decreased in the mice that were subcutaneously inoculated with miR-217 overexpression. (**D**) The expressions of Ki-67 and KRAS were measured by immunohistochemistry using tumor tissue. All data are shown as mean ± SD, $^{**}P<0.01$ compared to control.
Abbreviations: KRAS, Kirsten rat sarcoma viral oncogene homolog; miR-217, microRNA-217; miR-NC, microRNA negative control.

data indicated that miR-217 suppressed cervical cancer cell growth and induced apoptosis. To confirm these findings, the in vivo xenograft model was constructed using parental cells or miR-217-transfected SiHa cells. As shown in Figure 3A and B, the tumor growth of SiHa cells in the mice that were subcutaneously inoculated with miR-217-transfected cells was remarkably inhibited. Consistently, the tumor weight formed by parental cells was markedly heavier than the tumor formed by miR-217 overexpression cells (Figure 3C). The level of miR-217 was also upregulated in tumor tissue that was formed by miR-217-transfected SiHa cells compared to that in the tumor which was formed by parental SiHa cells (Figure S4). Meanwhile, ICH staining was conducted to assess the expressions of Ki-67 and KRAS in tumor tissue. Both lower levels of Ki-67 and KRAS were observed in the tissue derived from miR-217 overexpression cells than that in the control mice (Figure 3D). These data indicate that upregulation of miR-217 restrains the growth of cervical carcinoma cell in vivo.

miR-217 suppresses cervical carcinoma cell migration and invasion

We explored the role of miR-217 in the migration of cervical carcinoma cell using the wound healing assay. As shown in

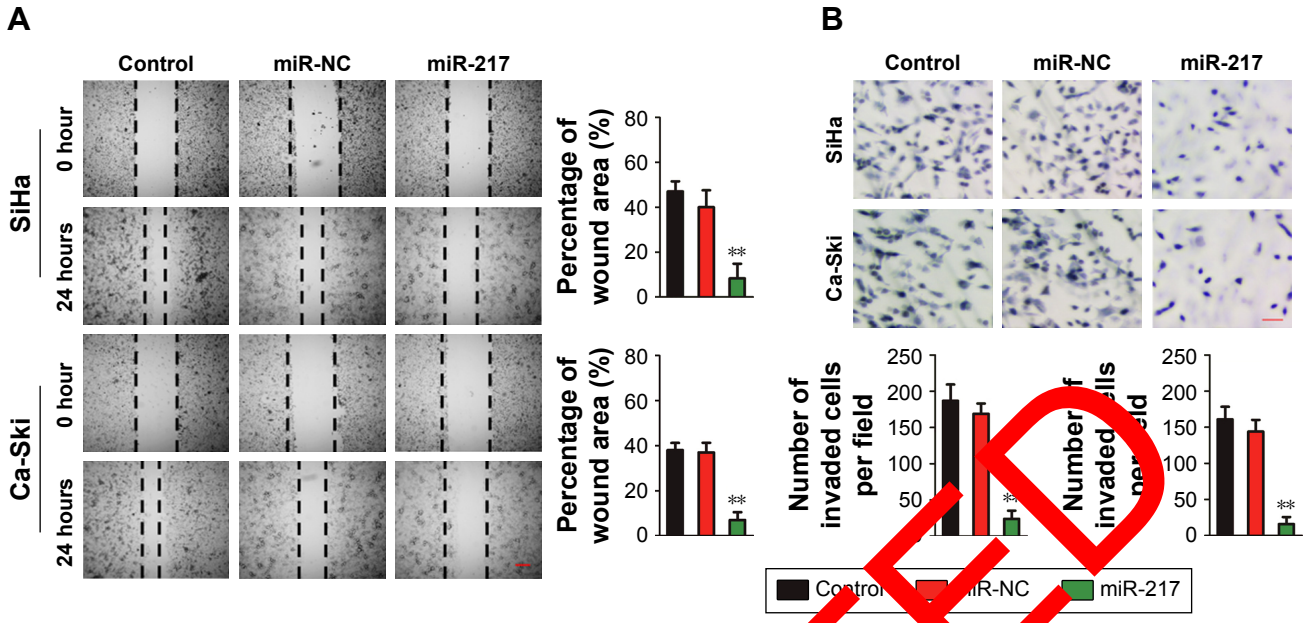

Figure 4 Overregulation of miR-217 decreases cervical cancer cell migration and invasion.
Notes: (**A**) The cervical cancer cells transfected with miR-217 exhibited significantly lower migratio bility t the control. (**B**) Ha and Ca-Ski cells were transfected with miR-217 or miR-NC, and then Transwell invasion assay was conducted. $^{**}P<0.01$ compared to control.
Abbreviations: miR-217, microRNA-217; miR-NC, microRNA negative control.

Figure 4A, both miR-217 overexpressing SiHa and Ca-Ski cells exhibited less migration capacities than miR-NC-transfected cell. The invasion of Ca-Ski and SiH ls was also detected after miR-217 was transfected into oth cell lines. Ca-Ski and SiHa cells that were tra fected w miR-217 had markedly lower invasion bilitie than t control cell (Figure 4B). Altogether, th e findi indicate that miR-217 inhibits cervical carc oma migration and invasion in vitro.

Identifying KRAS as the tar t of miR-217

Based on the onlin analysis tool, TargetScan prediction (http://www.target n.or vert_72/), the complementarity was found b een R-217 a the 3′-UTR of *KRAS* gene (Fig e 5A). To ve fy whether *KRAS* gene was the target miR-2 pMIR-REPORT™ vector containing wild-type) or mutant type (MUT) 3′-UTR of *KRAS* gene downstr m of the luciferase coding region was constructed (Figure 5A). HEK-293T cell was co-transfected with KRAS-WT or KRAS-MUT in combination with miR-217. As expected, the luciferase activity was remarkably decreased in the miR-217-transfected cell whereas the miR-217-mediated suppression of luciferase activity was partly abolished in cell that was co-transfected with miR-217 and KRAS-MUT (Figure 5B). Furthermore, the mRNA level of KRAS was analyzed by qRT-PCR in SiHa and Ca-Ski cells that were transfected with miR-217. No statistical significance was found between miR-217-transfected r miR-NC- nsfected cells (Figure 5C). Nevertheless, t protein pression of KRAS was decreased in miR-217-t fected SiHa and Ca-Ski cells compared to the p ntal cell (Figure 5D). Previous investigation indicates that miR-217 inhibits the proliferation, migration, and invasion of cancer cell via targeting AKT serine/threonine kinase 3 (AKT3) in thyroid cancer.[21] Then, we explored the inhibitory effect of miR-217 on the expression of AKT3. As shown in Figure S5, the protein expression of AKT3 was not significantly suppressed by miR-217 transfection. Collectively, these data suggest that *KRAS* is the direct target gene of miR-217, and miR-217 inhibits the expression of KRAS in cervical carcinoma cell.

Overexpression of miR-217 enhances the chemosensitivity of cervical carcinoma cells to cisplatin

Substantive studies suggested that the dysregulation of miRNA is associated with the chemoresistance of several cancers.[22] However, the relationship between miR-217 and chemosensitivity of cervical carcinoma is yet to be investigated. Hence, miR-217-overexpressing SiHa and Ca-Ski cells were treated with cisplatin (5, 10, 15, 20, and 25 μg/mL) for 24 hours. The CCK-8 assay indicated that the upregulation of miR-217 distinctly inhibited the cell viability in the presence of cisplatin (Figure 6A). Meanwhile, cisplatin treatment increased the level of miR-217 in Ca-Ski and SiHa cells. The level of miR-217 was increased by cisplatin in both time- and

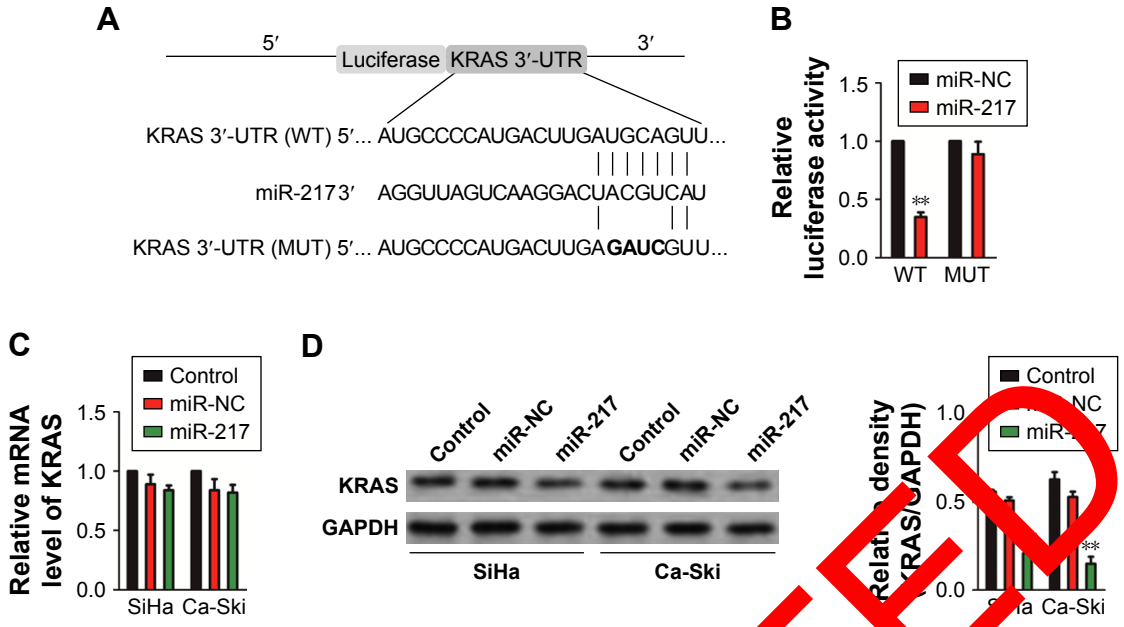

Figure 5 *KRAS* is a direct target of miR-217.

Notes: (**A**) A schematic representation of the reporter construct showing the WT 3′-UTR and MUT 3′-UTR of KRAS. (**B**) The pMIR-REPORT™ vector containing WT or MUT 3′-UTR of KRAS and miR-217 was co-transfected into 293T cell, and luciferase reporter assay was conducted. **P < 0.01 compared to miR-NC. (**C**) The expression of KRAS in SiHa and Ca-Ski cells transfected with miR-217 or miR-NC was determined by qRT-PCR (C) and immunoblotting analysis of KRAS in SiHa and Ca-Ski cells transfected with miR-217 or miR-NC. The experiment was independently repeated three times.

Abbreviations: KRAS, Kirsten rat sarcoma viral oncogene homolog; miR-217, microRNA-217; miR-NC, microRNA negative control; MUT, mutant type; qRT, quantitative real-time; WT, wild-type.

dose-dependent manners (Figure 6B). For further verification of these results, we then detected the mRNA and protein expression of KRAS in Ca-Ski and SiHa cells that were treated with cisplatin. As expected, both protein expression and mRNA level of KRAS were markedly inhibited after cells were treated with cisplatin (Figure 6C and D). Finally, we reduced the level of miR-217 in Ca-Ski and SiHa cells using anti-miR to further confirm the role of miR-217 on the chemotherapy-resistance of SiHa and Ca-Ski cells. When compared to miR-217, anti-miR-217 heightened cisplatin torrent in SiHa and Ca-Ski cells (Figure 6E). In conclusion, downregulation of miR-217 increased the chemosensitivity of cervical cancer cells to cisplatin.

Discussion

Sufficient investigations have demonstrated that miRNAs play crucial roles in the tumorigenesis and progression of various types of cancers, and serve as oncogenes or tumor suppressors via regulating their target genes.[22,23] In general, the levels of miRNAs which serve as tumor suppressors are relatively lower, whereas the levels of miRNAs which act as oncogenic miRNAs are relatively higher in cancers.[24] Therefore, miRNAs might function as the potential molecular markers to predict the clinical survival of patients with cancer. In cervical squamous cell carcinoma, the tumor-suppressive miRNA-29a inhibits the migration and invasion of cancer cells by targeting heat-shock protein 47.[25] Additionally, miRNA-181a enhances the chemoresistance of human cervical squamous cell carcinoma to cisplatin by targeting protein kinase C delta type.[26] miR-217, which is a special miRNA, acts as a tumor suppressor or an oncogene depending on the cancer type. For instance, miR-217 regulates either V-Ki-Ras2 KRAS or SirT1 in pancreatic cancer but directly targets *PTEN* in kidney cancer.[27] Additionally, miRNA-217 is identified as anti-oncogene and is associated with the drug-resistance of lung cancer.[17] In our study, we detected the levels of miR-217 in cervical carcinoma tissues and cell lines. The results suggested that miR-217 was downregulated in clinical cervical cancer tissues than that in adjacent normal tissues. Importantly, the alternation of miR-217 was closely associated with cervical cancer progression, which suggested that miR-217 might be a suppressive miRNA.

The growth, apoptosis, migration, and invasion assays were conducted using miR-217-transfected cervical cancer cell to investigate the roles of miR-217 in the progression of cervical carcinoma. Our results demonstrated that upregulating of miR-217 suppressed the growth of cervical carcinoma cell in vitro and in vivo. Moreover, we identified and confirmed that KRAS was the direct and functional target of miR-217 in cervical cancer. Luciferase reporter assay using HEK-293T cells that were transfected with miR-217 confirmed that miR-217 bound to the 3′-UTR of *KRAS*

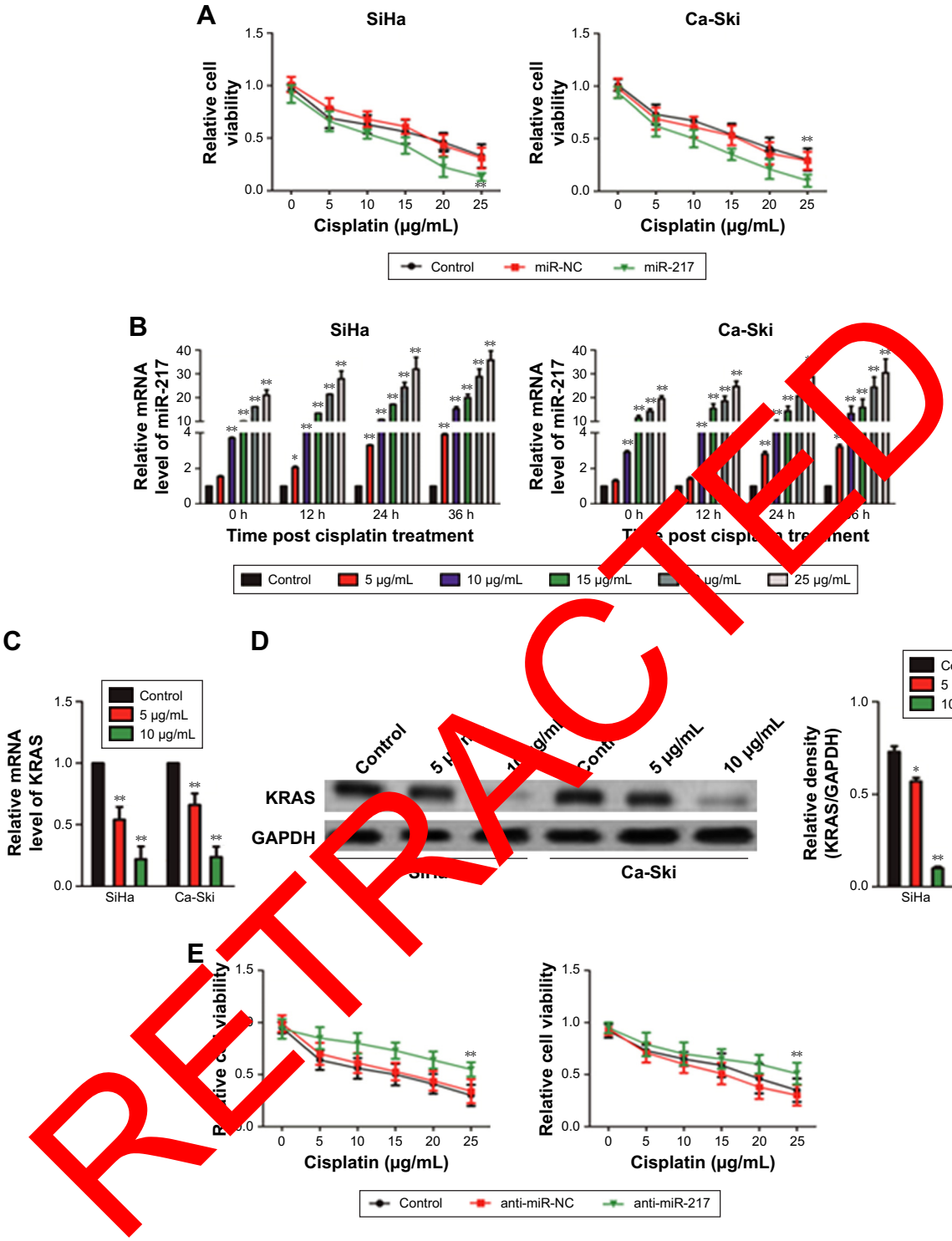

Figure 6 The effect of miR-217 on the chemoresistance of SiHa and Ca-Ski cells.
Notes: (**A**) The proliferation of SiHa and Ca-Ski cells that were treated with cisplatin were assessed by CCK-8 assay. (**B**) Effects of different concentrations and time of cisplatin treatment on the level of miR-217 in SiHa and Ca-Ski cells. (**C**) Effect of cisplatin on mRNA level of KRAS in SiHa and Ca-Ski cells. (**D**) Effect of cisplatin on the protein expression of KRAS in SiHa and Ca-Ski cells was determined by Western blotting. The experiment was independently repeated three times. (**E**) The effect of miR-217 down-expression on the sensitivity of cervical cancer cell was assessed by CCK-8. *$P<0.05$ and **$P<0.01$ compared to control cell.
Abbreviations: CCK-8, Cell Counting Kit-8; KRAS, Kirsten rat sarcoma viral oncogene homolog; miR-217, microRNA-217; miR-NC, microRNA negative control.

gene. In addition, overregulation of miR-217 inhibited the expression of KRAS in both cervical carcinoma cell lines. Nevertheless, no statistic difference in the mRNA level of KRAS was found in cells that were transfected with miR-217 or miR-NC, which indicates that miR-217 acted a regulator of *KRAS* gene at posttranscriptional level.

Cisplatin is a commonly used chemotherapeutic agent in cancer treatment, although the high doses of cisplatin

causes toxic effects, including ototoxicity and nephrotoxicity. Increasingly, research is showing that miRNAs dysregulation could alter the chemoresistance of cancer cell toward cisplatin.[28] In triple-negative breast cancer, miR-770 suppresses the chemoresistance through direct targeting of stathmin1.[29] In pancreatic cancer cell, miRNA-429 sensitizes cancer cell to gemcitabine via regulation of programmed cell death protein 4.[30] The current study also provided novel understanding about the correlation of miR-217 with chemoresistance of cervical carcinoma. Firstly, we demonstrated that overregulation of miR-217 reduced the cisplatin-resistance of cervical cancer cell. The proliferation of cervical cancer cell that was transfected with miR-217 was more significantly inhibited by cisplatin treatment compared to control cell. Meanwhile, cisplatin treatment increased the levels of miR-217 in cervical cancer cells, SiHa and Ca-Ski, in both time- and dose-dependent manners. Then, we further investigated the effect of cisplatin on the expression of KRS in cervical cancer cell. As expected, cisplatin treatment significantly decreased the mRNA levels and protein expressions of KRAS in SiHa and Ca-Ski. All these indicated that cisplatin increased the level of miR-217 and subsequently decreased the expressions of KRAS in cervical cancer cell. In order to confirm the core role of miR-217 in t regulation of cervical cancer cell toward cisplatin, SiHa an Ca-Ski cells were transfected with anti-miR-217 reduce the level of miR-217. Then, the anti-miR-21 -trans cted cell was subjected to proliferation assay i e pres of cisplatin. As expected, downregulation miR-2 decreased the sensitivity of cervical cancer ce cisplatin. erefore, cisplatin combining with miR-21 migh erve as a potential therapeutic strategy for pati ts with cervi carcinoma.

Conclusion

In conclusion, miR-217 s down gulated in cervical carcinoma, a functi ned as ti-oncogene in cervical carcinoma regul KRAS. Upregulation of miR-217 significantly i ted cervical carcinoma cell growth and metastasis, and re forced the chemosensitivity of cervical carcinoma cell to cisplatin.

Disclosure

The authors report no conflicts of interest in this work.

References

1. Song B, Ding C, Chen W, Sun H, Zhang M, Chen W. Incidence and mortality of cervical cancer in China, 2013. *Chin J Cancer Res*. 2017; 29(6):471–476.
2. Zhang B, Wei CY, Chang KK, et al. TSLP promotes angiogenesis of human umbilical vein endothelial cells by strengthening the crosstalk between cervical cancer cells and eosinophils. *Oncol Lett*. 2017; 14(6):7483–7488.
3. Xu H, Yuan Y, Wu W, et al. Hypoxia stimulates invasion and migration of human cervical cancer cell lines HeLa/SiHa through the Rab11 trafficking of integrin αvβ3/FAK/PI3K pathway-mediated Rac1 activation. *J Biosci*. 2017;42(3):491–499.
4. Shu XL, Fan CB, Long B, Zhou X, Wang Y. The anti-cancer effects of cisplatin on hepatic cancer are associated with modulation of miRNA-21 and miRNA-122 expression. *Eur Rev Med Pharmacol Sci*. 2016; 20(21):4459–4465.
5. Poudyal D, Herman A, Adelsberger JW, et al. A novel microRNA, hsa-miR-6852 differentially regulated by interleukin-27 induces necrosis in cervical cancer cells by downregulating the Fo l expression. *Sci Rep*. 2018;8(1):900.
6. Zhao J, Li B, Shu C, Ma Y, Gong Y ownregulation f miR-30a is associated with proliferation and inv on via targeti MEF2D in cervical cancer. *Oncol Lett*. 201 4(6): –7442.
7. Akçakaya P, Ekelund S, Ko enko I, et al iR-18 nd miR-133b deregulation is associat with ove l surv d metastasis in colorectal cancer. *Int J ol*. 201 9(2):311–318.
8. Zou Q, Wu H, Fu F W, P hou M. RK suppresses the proliferation and metast s of breast c er cell l s through up-regulation of miR-185 tars IMGA2. *Arch m Biophys*. 2016;610:25–32.
9. Hua FF, L SS, Z LH, et al. MRNA-338-3p regulates cervical cancer cells proliferation targeting MACC1 through MAPK signaling pat . *Eur Rev Med Ph acol Sci*. 2017;21(23):5342–5352.
10. Z u H, Han C, Wu T. MiR-17-92 cluster promotes hepatocarcinogenesis. *Carcinogen is*. 2015;36(10):1213–1222.
11. S, Huang Y u X. Mir-451 correlates with prognosis of renal ce carcinoma p ents and inhibits cellular proliferation of renal cell carcin *Sci Monit*. 2016;22:183–190.
12. ei C, Du F, Sun L, et al. miR-143 and miR-145 inhibit gastric cancer ce ation and metastasis by suppressing MYO6. *Cell Death Dis*. 2017;8(10):e3101.
13. Lin H, Dai T, Xiong H, et al. Unregulated miR-96 induces cell proliferation in human breast cancer by downregulating transcriptional factor FOXO3a. *PLoS One*. 2010;5(12):e15797.
14. Li X, Deng SJ, Zhu S, et al. Hypoxia-induced lncRNA-NUTF2P3-001 contributes to tumorigenesis of pancreatic cancer by derepressing the miR-3923/KRAS pathway. *Oncotarget*. 2016;7(5):6000–6014.
15. Menghini R, Casagrande V, Cardellini M, et al. MicroRNA 217 modulates endothelial cell senescence via silent information regulator 1. *Circulation*. 2009;120(15):1524–1532.
16. Huang L, Li F, Deng P, Hu C. MicroRNA-223 promotes tumor progression in lung cancer A549 cells via activation of the NF-κB signaling pathway. *Oncol Res*. 2016;24(6):405–413.
17. Guo J, Feng Z, Huang Z, Wang H, Lu W. MicroRNA-217 functions as a tumour suppressor gene and correlates with cell resistance to cisplatin in lung cancer. *Mol Cells*. 2014;37(9):664–671.
18. Cheung CC, Lun SW, Chung GT, et al. MicroRNA-183 suppresses cancer stem-like cell properties in EBV-associated nasopharyngeal carcinoma. *BMC Cancer*. 2016;16:495.
19. Chai S, Tong M, Ng KY, et al. Regulatory role of miR-142-3p on the functional hepatic cancer stem cell marker CD133. *Oncotarget*. 2014; 5(14):5725–5735.
20. Takahashi Y, Forrest AR, Maeno E, Hashimoto T, Daub CO, Yasuda J. MiR-107 and MiR-185 can induce cell cycle arrest in human non small cell lung cancer cell lines. *PLoS One*. 2009;4(8):e6677.
21. Li J, Ping Z, Ning H. MiR-218 impairs tumor growth and increases chemo-sensitivity to cisplatin in cervical cancer. *Int J Mol Sci*. 2012; 13(12):16053–16064.
22. Chong GO, Jeon HS, Han HS, et al. Differential microRNA expression profiles in primary and recurrent epithelial ovarian cancer. *Anticancer Res*. 2015;35(5):2611–2617.

23. Ling S, Ruiqin M, Guohong Z, Ying W. Expression and prognostic significance of microRNA-451 in human epithelial ovarian cancer. *Eur J Gynaecol Oncol*. 2015;36(4):463–468.
24. Qin CZ, Lou XY, Lv QL, et al. MicroRNA-184 acts as a potential diagnostic and prognostic marker in epithelial ovarian cancer and regulates cell proliferation, apoptosis and inflammation. *Pharmazie*. 2015;70(10):668–673.
25. Yamamoto N, Kinoshita T, Nohata N, et al. Tumor-suppressive microRNA-29a inhibits cancer cell migration and invasion via targeting HSP47 in cervical squamous cell carcinoma. *Int J Oncol*. 2013;43(6):1855–1863.
26. Ke G, Liang L, Yang JM, et al. miR-181a confers resistance of cervical cancer to radiation therapy through targeting the pro-apoptotic PRKCD gene. *Oncogene*. 2013;32(25):3019–3027.
27. Zhao WG, Yu SN, Lu ZH, Ma YH, Gu YM, Chen J. The miR-217 microRNA functions as a potential tumor suppressor in pancreatic ductal adenocarcinoma by targeting KRAS. *Carcinogenesis*. 2010;31(10):1726–1733.
28. Dasari S, Tchounwou PB. Cisplatin in cancer therapy: molecular mechanisms of action. *Eur J Pharmacol*. 2014;740:364–378.
29. Li Y, Liang Y, Sang Y, et al. MiR-770 suppresses the chemo-resistance and metastasis of triple negative breast cancer via direct targeting of STMN1. *Cell Death Dis*. 2018;9(1):14.
30. Yu G, Jia B, Cheng Y, et al. MicroRNA-429 sensitizes pancreatic cancer cells to gemcitabine through regulation of PDCD4. *Am J Transl Res*. 2017;9(11):5048–5055.

Supplementary materials

Table S1 Clinicopathological characteristics and expression of miR-217 in the study patients with cervical cancer

Clinical parameters	miR-217		*P*-value
	High	Low	
Age (years)			0.109
≤55	12	18	
>55	15	20	
FIGO stage			0.031
I–II	8	17	
III–IV	17	23	
Histology			0.016
Squamous	21	28	
Others	11	5	
Metastasis			0.008
Yes	16	22	
No	17	10	

Abbreviation: FIGO, International Federation of Gynecology and Obstetrics.

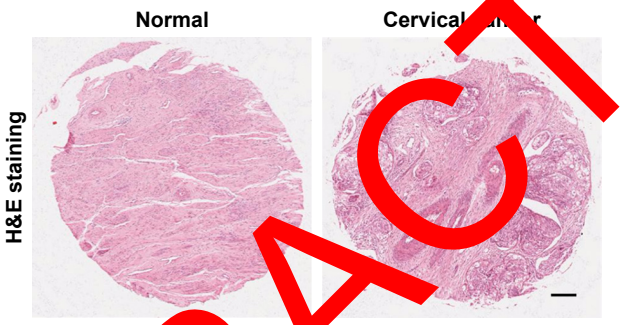

Figure S1 Cervical cancer tissues and normal cervical tissues were examined by H&E staining.
Note: Scale bar represents 200 μm.

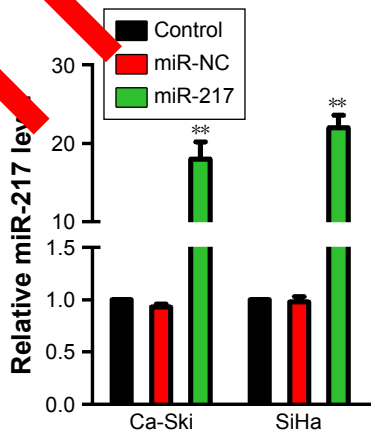

Figure S2 Cervical cancer cells, Ca-Ski and SiHa, were transfected with miR-NC or miR-217, and the level of miR-217 was detected using qRT-PCR assay. $^{**}P<0.01$ compared to control.
Abbreviations: miR-217, microRNA-217; miR-NC, microRNA negative control; qRT, quantitative real-time.

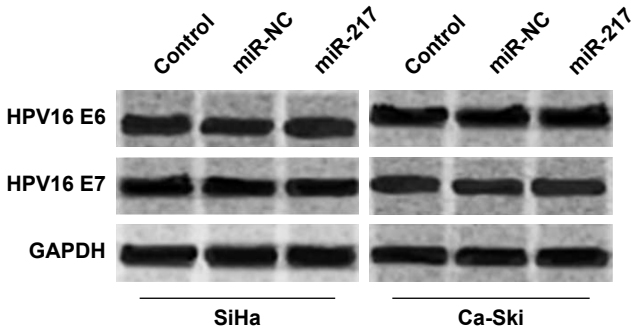

Figure S3 Cervical cancer cells, Ca-Ski and SiHa, were transfected with miR-NC or miR-217. The expressions of HPV16 E6 and HPV16 E7 were measured by Western blotting assay.
Abbreviations: miR-217, microRNA-217; miR-NC, microRNA negative control.

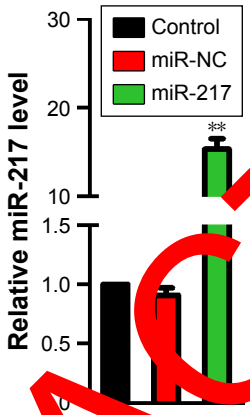

Figure S4 The level of miR-217 in tumor tissue that was formed by miR-217 transfected SiHa cells or the tumor which was formed by parental SiHa cells was detected using qRT-PCR assay. **$P<0.01$ compared to control.
Abbreviations: miR-217, microRNA-217; miR-NC, microRNA negative control; qRT, quantitative real-time.

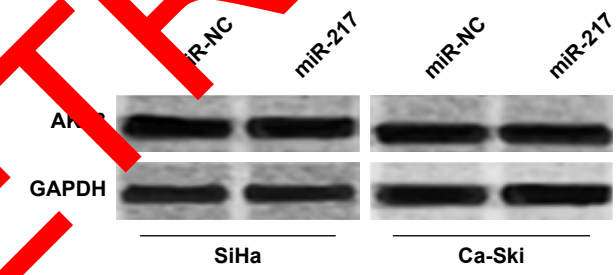

Figure S5 Cervical cancer cells, Ca-Ski and SiHa were transfected with miR-NC or miR-217.
Note: The expression of AKT3 were measured by Western blotting assay.
Abbreviations: AKT3, AKT serine/threonine kinase 3; miR-217, microRNA-217; miR-NC, microRNA negative control.