OncoTargets and Therapy

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ORIGINAL RESEARCH

RETRACTED ARTICLE: MicroRNA -381 enhances radiosensitivity in esophageal squamous cell carcinoma by targeting X-linked inhibitor of apoptosis protein

This article was published in the following Dove Press journal:
OncoTargets and Therapy
11 May 2017
Number of times this article has been viewed

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Background: Increasing evidence indicates that radioresistance remains a major problem in the treatment of patients with esophageal squamous cell carcinoma (ESCC). This study was designed to investigate the expression of microRNA-381 (miR-381) and its function in the radioresistance of ESCC.

Methods: In this study, miR-381 expression was first detected in ESCC cell lines and tissue samples by quantitative real-time polymerase chain reaction (qRT-PCR). Then, the effects of miR-381 expression on growth, apoptosis, and radiosensitivity of ESCC cells were analyzed by MTT, colony formation, and flow cytometry, respectively. Dual-luciferase reporter assays were performed to validate the regulation of a putative target of miR-381, in corroboration with qRT-PCR and Western blotting assays.

Results: ESCC cell lines or tissues were found to express significantly lower miR-381 than normal esophageal epithelial cells or adjacent normal tissues, respectively. Ectopic expression of miR-381 in ESCC cell lines blocked proliferation, reduced colony formation, enhanced apoptosis, and increased radiosensitivity by enhancing irradiation-induced apoptosis. In addition, dual-luciferase reporter assays showed that miR-381 binds to the 3′-untranslated region of X-linked inhibitor of apoptosis protein (XIAP), suggesting that XIAP should be a direct target of miR-381. Re-expression of miR-381 suppressed XIAP protein expression in ESCC cells, and the effects of miR-381 upregulation on ESCC cells were found to be similar with silencing of XIAP. In addition, XIAP mRNA expression significantly increased in ESCC tissues and was inversely correlated with miR-381 expression.

Conclusion: The results of this study suggest that miR-381/XIAP pathway contributed to the growth inhibition, increase in apoptosis, and enhancement of radiosensitivity in ESCC cells Therefore, miR-381 may be a potential therapeutic target in human ESCC.

Keywords: miR-381, esophageal squamous cell carcinoma, XIAP, growth, apoptosis

Introduction

Esophageal squamous cell carcinoma (ESCC) is the predominant histological type of esophageal cancer with high incidence and mortality rates, and it accounts for 90% of esophageal cancer cases in the northern and central China.[1,2] Despite progress in recent years in treatment of esophageal cancer, the long-term survival rate remains disappointing.[3] Esophageal carcinogenesis is a multifactor-mediated progressive process involving genetic and epigenetic changes.[2] Thus, it is imperative to understand the molecular mechanisms that underlie ESCC development, which may be helpful in identifying novel therapeutic targets of ESCC.

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http://dx.doi.org/10.2147/OTT.S134551

MicroRNAs (miRNAs) are small non-coding RNAs of 18–24 nucleotides in length, which regulate gene expression by promoting degradation or repressing translation of their target mRNAs.[4] Increasing evidence shows that dysregulated miRNAs function as key regulators of biological processes including proliferation, differentiation, apoptosis, development, and malignant transformation.[5,6] In a previous work, differential miRNA-381 (miR-381) expression was found in ESCC tissues and cells with different levels of radiosensitivity, and miR-381 was found to act as a key regulator of radiosensitivity in ESCC.[7] In addition, the research confirmed that the level of X-linked inhibitor of apoptosis protein (XIAP) expression was positively correlated to progression and prognosis of ESCC.[8] XIAP was predicted as a candidate target gene of miR-381 by target prediction software such as TargetScan, PicTar, and miRanda. However, the molecular mechanisms behind the regulation of ESCC radiosensitivity by miR-381 remain to be further elucidated.

The present study shows that miR-381 is downregulated in ESCC cell lines and tissues. Additional studies show that re-expression of miR-381 inhibits growth, enhances apoptosis, and reverses radioresistance in ESCC cells by directly targeting XIAP. These results indicate that re-expression of miR-381 may be a potential strategy in ESCC therapy.

Materials and methods

Tissue samples

Sixteen paired ESCC and adjacent normal tissues were collected from the Department of Pathology in Tangdu Hospital of Fourth Military Medical University between 2013 and 2014, after informed consent had been obtained. The Institutional Ethics Committee approval for this study had been obtained from the Tangdu Hospital Institutional Review Board. None of the patients had received preoperative radiotherapy or chemotherapy, and all ESCC cases were pathology-confirmed. All tumor samples were snap-frozen in liquid nitrogen, and transferred to Trizol reagent (Invitrogen, Carlsbad, CA, USA) immediately after harvest to prevent mRNA degradation. Samples were stored at –80°C until processed.

Cell culture

Two ESCC cell lines (TE10 and TE11) and a normal human esophageal epithelial cell (HET-1A) were purchased from Cell Bank of Shanghai Institutes for Biological Sciences (Chinese Academy of Sciences, Shanghai, China), and cultured in RPMI 1640 supplemented with 10% fetal bovine serum (Lonza Corp, Basel, Switzerland) and 1% penicillin–streptomycin (Invitrogen) in a humidified atmosphere of 5% CO_2 at 37°C.

Transfection of plasmids

For ectopic expression of miR-381 or knockdown of XIAP, pGLV3/miR-381 (or pGLV3/miR-NC vector) or pGLV3/shXIAP (pGLV3/shcontrol) was purchased from GenePharma (Shanghai, China). Transfections were performed using Lipofectamine™ 2000 (Invitrogen) according to the manufacturer's instructions. Cells were transfected with recombinant DNA vectors containing a Puromycin selection marker and selected on Puromycin (Sigma-Aldrich, St Louis, MO, USA) at 0.6 µg/mL for 4 weeks. Single clones were maintained in G418 at 0.1 µg/mL.

qRT-PCR assay

Total RNA was isolated using Trizol (Invitrogen), and 10 µg RNA was used to synthesize cDNA with Taq-Man® MicroRNA Reverse Transcription Kit (Applied Biosystems). Quantitative real-time polymerase chain reaction (qRT-PCR) was performed by BioRad iQ Real-Time PCR Detection System with a SYBR Green I Master Mix (TAKAR, Otsu, Japan). The conditions were as follows: 95°C for 3 min, and then 40 cycles of 95°C for 30 s, 62°C for 40 s, and 72°C for 15 s, followed by 5 min at 72°C and a hold at 4°C. A ΔCt (target–reference) was calculated, which is equal to the difference between threshold cycles for miR-381 (target) and the threshold cycle for U6 RNA (reference) (ΔCt (target-reference) = Ct target − Ct reference). The fold-change between patient or cell sample and a normal control for miR-381 or XIAP was calculated by the $2^{-\Delta\Delta Ct}$ method.

Western blotting assay

The cells were lysed using the mammalian protein extraction reagent RIPA lysis buffer (Beyotime, Haimen, China) supplemented with a protease inhibitor cocktail (Roche, Basel, Switzerland), and phenylmethylsulfonyl fluoride (Roche). In all, protein extract was separated by 10% SDS-PAGE, transferred to nitrocellulose membrane (Sigma-Aldrich), and incubated with specific antibodies. Gels were scanned and quantified by densitometry using the Quantity-One software (BioRad, Hercules, CA, USA). Rabbit anti-XIAP, cleaved caspase-3, total caspase-3, cleaved PARP, and total PARP were obtained from PharMingen (San Diego, CA, USA). GAPDH antibody was used as a control.

MTT assays

MTT assay (Sigma-Aldrich) was used to measure cell growth. In brief, cells were seeded at a density of 5×10^3 cells/well in 96-well plates at a final volume of 180 µL and incubated. Two hundred microliters of MTT (5 mg/mol) was added to each well, and then incubated for 4 h at 37°C. Reactions were

stopped by lysing cells with 150 µL dimethyl sulfoxide for 5 min. Optical density was determined on a multidetection microplate reader (BMG LABTECH, Cary, NC, USA) at a wavelength of 490 nm.

Colony formation assay

Cells were trypsinized to single-cell suspensions and seeded into six-well plates at 700 cells/well for colony formation assay. After 14 days of culture in a humidified atmosphere of 5% CO_2 at 37°C, colonies were stained with Giemsa solution, and the colony number was counted. Each experiment was performed in triplicate.

Flow cytometric detection of apoptosis

Cells were harvested after pretreatment, washed twice with cold phosphate-buffered saline, fixed in ice-cold ethanol, and incubated overnight at −20°C. Cells were incubated with annexin V/propidium iodide (Sigma-Aldrich) for 15 min at room temperature. A minimum of 1.0×10^6 cells were collected and analyzed using FACS (BD, Franklin Lakes, NJ, USA), and the percentage of cells with apoptotic nuclei (% apoptosis) was calculated.

Clonogenic survival assay

After being cultured overnight, cells were seeded into six-well plates followed by radiation (0.0, 2.0, 4.0, 6.0 and 8.0 Gy), and cultured for another 14 days. Colonies (>50 cells) were fixed with pre-chilled ethanol and stained with crystal violet. Colonies were counted by an inverted microscope in five random fields (Olympus, Tokyo, Japan). The surviving fraction was calculated as follows: number of colonies/number of seeded cells. All experiments were conducted in triplicate.

Dual-luciferase reporter assay

Wild-type (WT) and mutant (mut) 3′-UTR of XIAP were cloned into the pGL3-Basic vector (Promega, Madison, WI, USA), respectively, and then pGL3/XIAP/3′-UTR-WT and pGL3/XIAP/3′-UTR-mut recombinant vector were constructed after sequencing. HEK-293 cells were transiently cotransfected with reporter plasmids and pGCMV/miR-381 (or pGCMV/miR-NC) and harvested in reporter lysis buffer. The luciferase activity was measured after 48-h transfection by using the Dual-Luciferase Reporter Assay System (Promega). Firefly luciferase activity was normalized to Renilla luciferase activity for each transfected well.

Statistical analysis

All values were presented as mean ± standard deviation. Statistical significance was analyzed by χ^2 test and *t*-test using SPSS (version 13.0; SPSS Inc., Chicago, IL, USA). Correlations were evaluated by Spearman's rank correlation coefficients. $P<0.05$ was considered to indicate statistical significance.

Results

miR-381 expression is downregulated in ESCC cells and tissues

The qRT-PCR results showed that miR-381 expression in TE10 and TE11 was significantly lower than those observed in HET-1A ($P<0.01$; Figure 1A). It was also observed that miR-381 expression was significantly decreased in ESCC tissues compared to the adjacent normal tissues ($P<0.01$; Figure 1B). These data indicate that downregulation of miR-381 may play a critical role in the development of ESCC.

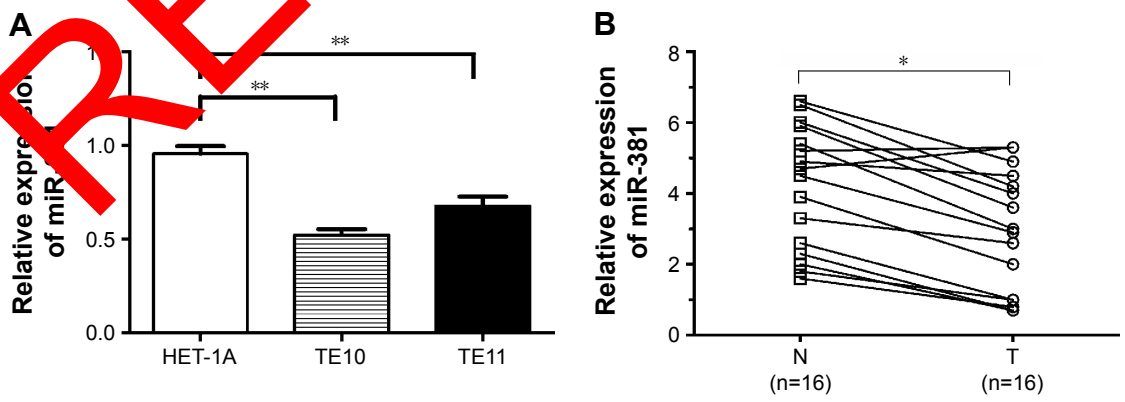

Figure 1 qRT-PCR of miR-381 expression in ESCC cells and tissue samples.

Notes: (**A**) qRT-PCR detection of miR-381 expression in TE10 and TE11 and HET-1A cells. (**B**) qRT-PCR detection of miR-381 expression in 16 paired ESCC and adjacent normal tissues. U6 was used as an internal control. Each assay was performed at least in triplicate. Corresponding *P*-values determined by paired-samples *t*-tests are indicated. *$P<0.05$ and **$P<0.01$ vs control.

Abbreviations: T, ESCC tissues; N, adjacent normal tissues; qRT-PCR, quantitative real-time polymerase chain reaction; miR-381, microRNA-381; ESCC, esophageal squamous cell carcinoma.

Re-expression of miR-381 inhibits growth and enhances apoptosis in ESCC cells

To detect the effects of miR-381 on ESCC cells, pGLV3/miR-381 or pGLV3/miR-NC was stably transfected into TE10 and TE11. qRT-PCR was performed to confirm the upregulation of miR-381 (Figure 2A). MTT and colony formation assays were performed to examine the effects of miR-381 expression on ESCC growth, which showed that miR-381 expression resulted in reduced growth and colony formation capacity (Figure 2B and C). Flow cytometric analysis showed that the apoptosis of ESCC cells was enhanced by miR-381 re-expression (Figure 2D). Furthermore, upregulation of miR-381 increased expression levels of cleaved caspase-3 (c-caspase-3) and cleaved PARP (c-PARP), and decreased

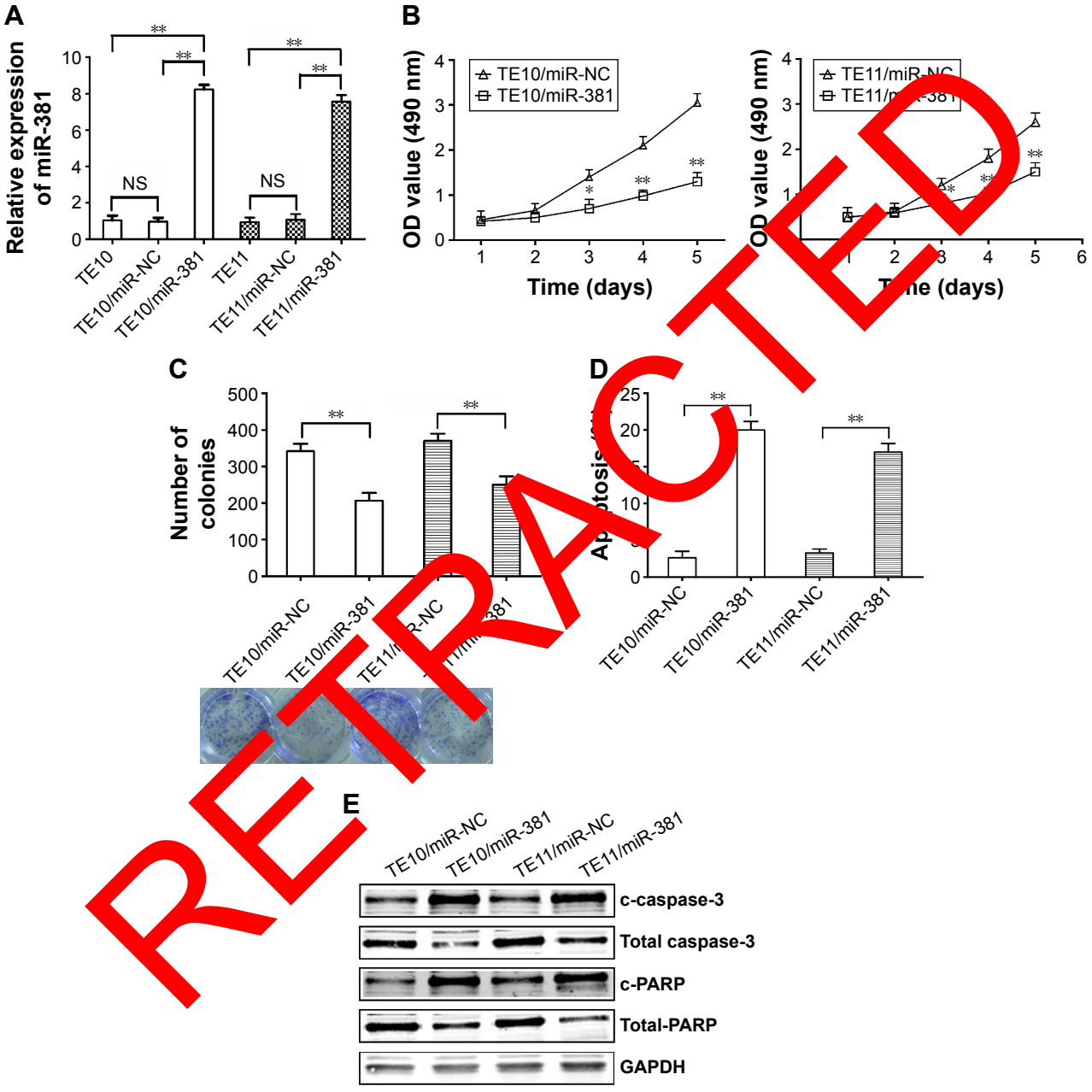

Figure 2 Effects of miR-381 expression on growth, colony formation, and apoptosis in ESCC.

Notes: (**A**) qRT-PCR detection of miR-381 expression in mock or stably transfected TE10 and TE11 cells. U6 was used as an internal control. (**B**) MTT analysis of growth of TE10 and TE11 cells following stable transfection with pGLV3/miR-NC and pGLV3/miR-381, respectively. (**C**) Colony formation assay was performed. (**D**) Flow cytometric analysis of apoptosis in TE10 and TE11 cells stably transfected with pGLV3/miR-NC and pGLV3/miR-381, respectively. (**E**) Western blot detection of c-caspase-3, total caspase-3, c-PARP, and total PARP in the stably transfected TE10 and TE11 cells. GAPDH was used as an internal control. Each experiment was performed at least in triplicate. *$P<0.05$ and **$P<0.01$ vs control.

Abbreviations: miR-381, microRNA-381; ESCC, esophageal squamous cell carcinoma; qRT-PCR, quantitative real-time polymerase chain reaction; NS, nonsignificant; OD, optical density; NC, negative control.

expression levels of total caspase-3 and PARP (Figure 2E). Therefore, re-expression of miR-381 can induce apoptosis of ESCC cells, which may be associated with caspase-3-dependent pathway.

Re-expression of miR-381 increases radiosensitivity in ESCC cells by enhancing irradiation-induced apoptosis

To further determine the regulation of ESCC radiosensitivity by miR-381, ESCC cells were exposed to various doses of irradiation (0.0, 2.0, 4.0, 6.0, and 8.0 Gy). The results showed that overexpression of miR-381 resulted in decreased growth of ESCC cells (Figure 3A). Similarly, when exposed to irradiation (6.0 Gy), colony formation capacity of TE10/miR-381 or TE11/miR-381 was reduced in comparison with TE10/miR-NC or TE11/miR-NC cells (Figure 3B). Moreover, it was found that re-expression of miR-381 promoted radiation-induced apoptosis of ESCC cells (Figure 3C). Ectopic expression of miR-381 induced by irradiation upregulated the expression of c-caspase-3 and c-PARP proteins in ESCC cells (Figure 3D). Together, these data suggest that upregulation of miR-381 enhances the radiosensitivity of ESCC by increasing irradiation-induced apoptosis.

XIAP as a direct target of miR-381 in ESCC cells

miRNA databases (TargetScan, miRanda, and MiRDB) were searched for potential target genes of miR-381. A putative miR-381-binding site was identified located within the 3′-UTR of XIAP. To further assess whether XIAP is a direct target of miR-381, the luciferase reporter vector with the XIAP 3′-UTR including the putative target site for miR-381 downstream of the luciferase gene (pLUC/XIAP/3′-UTR-wt) and a mutant version (pLUC/XIAP/3′-UTR-mut) were constructed (Figure 4A). HEK-293 cells were transiently cotransfected with appropriate plasmids encoding either miR-NC or miR-381 mimics. Then, luciferase activities were measured. Data indicated that miR-381 inhibited luciferase activity compared with the miR-NC group (Figure 4B), but had no effect in vector group containing XIAP/3′-UTR-mut, suggesting that miR-381 interacts directly with the 3′-UTR of XIAP mRNA. Western blot results suggested that XIAP was regulated by miR-381 in TE10 and TE11 cells, as re-expression of miR-381 decreased expression of XIAP protein in ESCC cells (Figure 4C). Collectively, these results indicate a direct interaction between miR-381 and XIAP in ESCC.

Silencing of XIAP inhibits growth, increases apoptosis, and enhances radiosensitivity in ESCC cells

Since XIAP was directly targeted by miR-381, it was hypothesized that miR-381 might increase radiosensitivity of ESCC via downregulation of XIAP protein. In order to validate this hypothesis, pGLV3/shXIAP or pGLV3/shcontrol was constructed and stably transfected into TE10 (TE10/shXIAP or TE10/shcontrol) and TE11 (TE11/shXIAP or TE11/shcontrol) cells. Western blot confirmed the decreased expression of XIAP protein in TE10/shXIAP or TE11/shXIAP cells compared with mock TE10 or TE11, and TE10/shcontrol or TE11/shcontrols (Figure 5A). MTT and colony formation assays revealed that silencing of XIAP inhibited growth and colony formation in ESCC cells (Figure 5B and C). Flow cytometric analysis further showed that XIAP silencing resulted in increased caspase-3-dependent apoptosis in ESCC cells (Figure 5D and E). Furthermore, XIAP silencing increased the radiosensitivity of ESCC cells by enhancing irradiation-induced caspase-3-dependent apoptosis (Figure 6A–C). Therefore, the effects of XIAP silencing were similar to that of miR-381 upregulation in ESCC cells.

XIAP is upregulated in ESCC tissues and is inversely correlated with miR-381 expression

The expression of XIAP mRNA was further examined in HET-1A, TE10, and TE11 cells by qRT-PCR, and it was found that XIAP mRNA was highly expressed in all tested ESCC cell lines, whereas its expression levels were substantially lower in normal HET-1A cell line (Figure 7A). In addition, the expression of XIAP mRNA in 16 paired ESCC and adjacent normal tissues showed that XIAP mRNA in ESCC tissues was elevated ($P<0.001$; Figure 7B). It was observed that the expression level of XIAP mRNA inversely correlated with the expression level of miR-381 in ESCC tissues (Pearson's correlation, $r=-0.687$; $P<0.001$; Figure 7C). Therefore, the XIAP mRNA expression is negatively correlated with miR-381 expression in ESCC tissues.

Discussion

In the present study, it was found that miR-381 was downregulated in ESCC cell lines and tissues. Specifically, the ectopic expression of miR-381 in ESCC cells was found to result in growth suppression, enhanced apoptosis, and increased radiosensitivity. Luciferase reporter assay and the functional assay of XIAP silencing verified that XIAP, a member of the inhibitor of apoptosis family of proteins, was a functional and

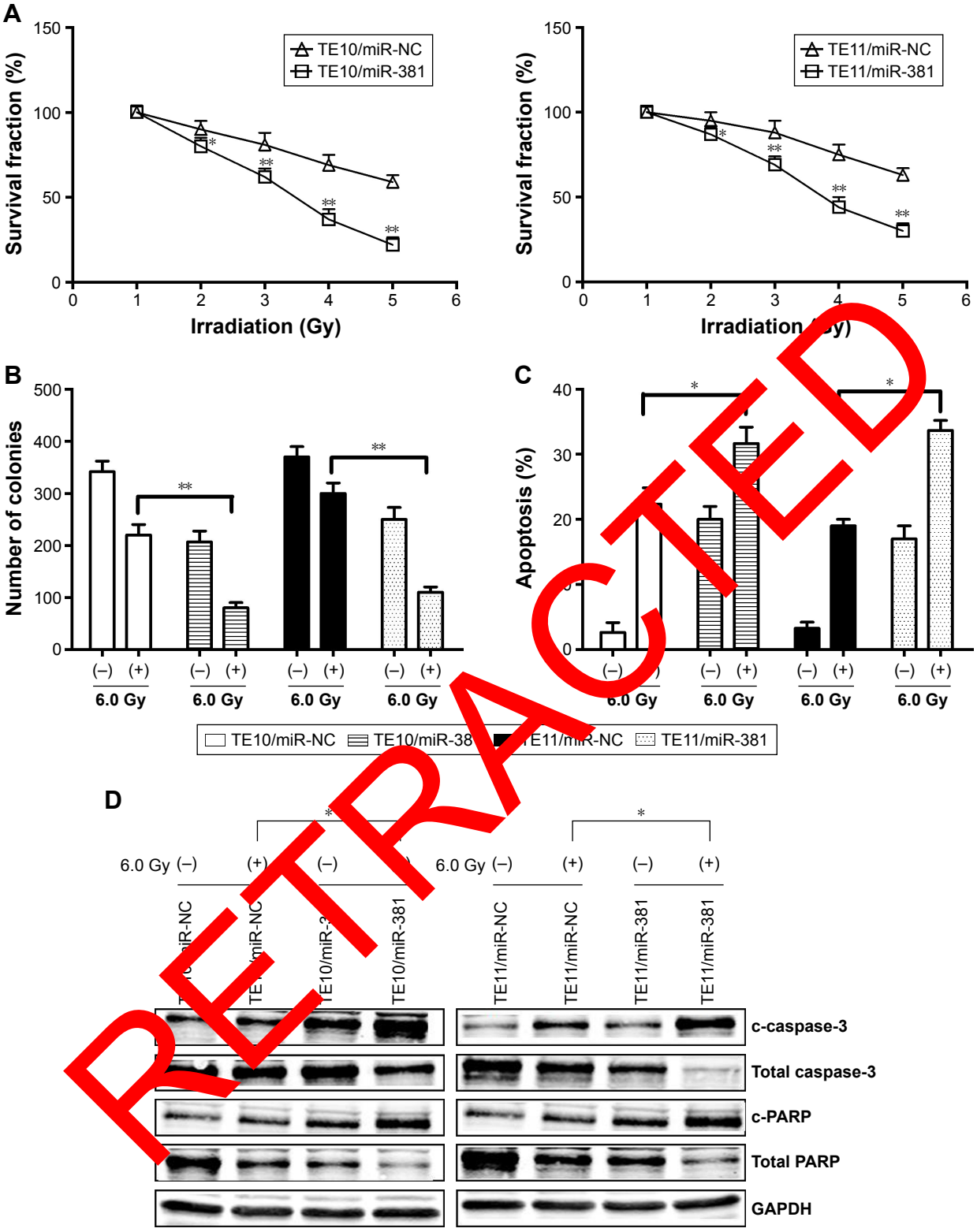

Figure 3 Effect of miR-381 expression on radiosensitivity of ESCC cells.

Notes: (**A**) Radiosensitization by expression of miR-381 was evaluated based on clonogenic cell survival assays. Stably transfected TE10 and TE11 cells were exposed to various doses of radiation prior to plating. (**B**) Colony formation assay was performed. (**C**) Flow cytometric detection of apoptosis in stably transfected TE10 and TE11 cells with or without irradiation (6.0 Gy). (**D**) Western blot detection of c-caspase-3, total caspase-3, cleaved c-PARP, and total PARP proteins in the stably transfected TE10 and TE11 cells with or without irradiation (6.0 Gy). GAPDH was used as an internal control. Each experiment was performed at least in triplicate. *$P<0.05$ and **$P<0.01$ vs control.

Abbreviations: miR-381, microRNA-381; ESCC, esophageal squamous cell carcinoma; NC, negative control.

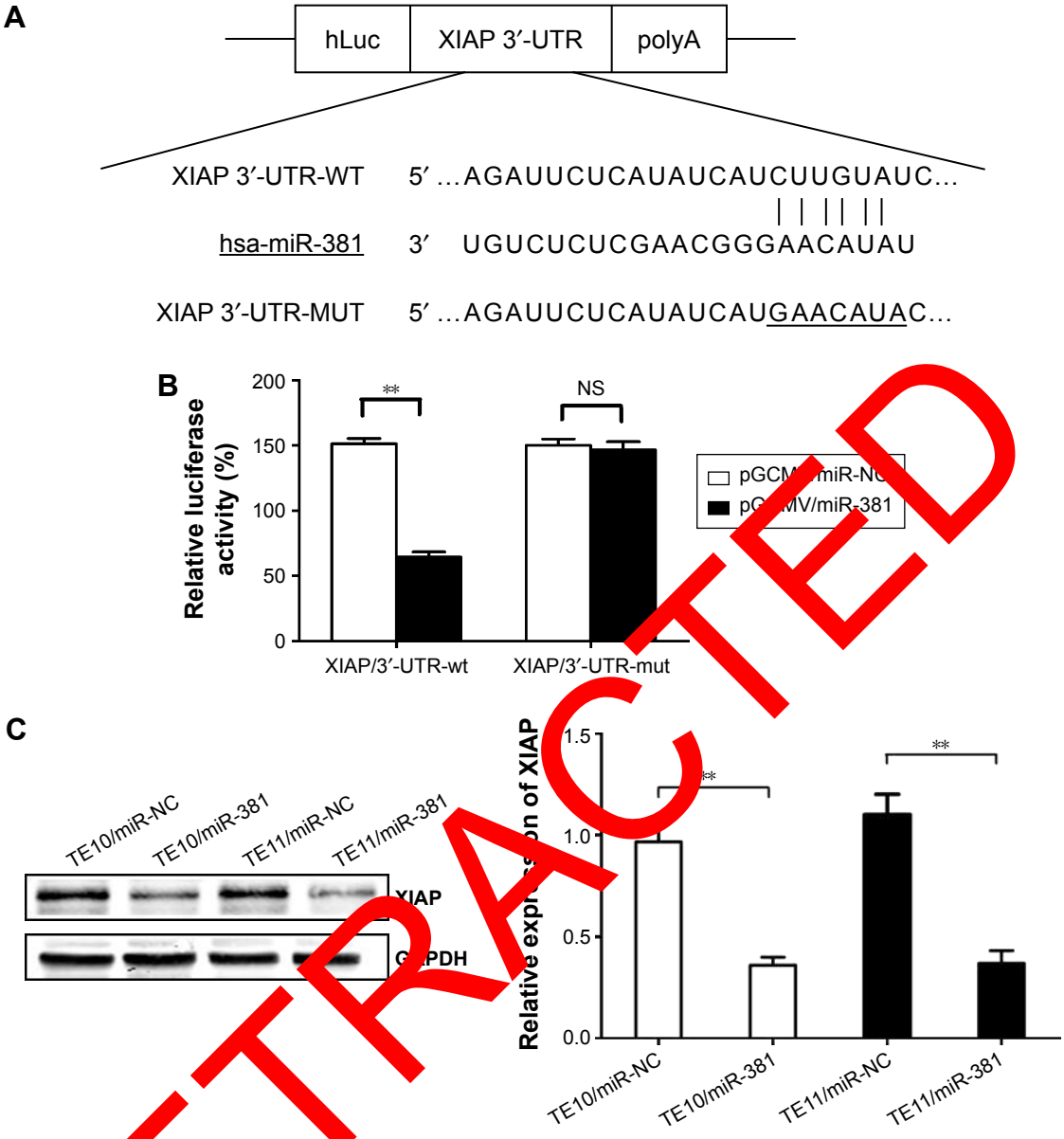

Figure 4 miR-381 binds to the 3′-UTR of XIAP mRNA.
Notes: (**A**) A human XIAP 3′-UTR fragment containing wild-type or mutant miR-381-binding sequence cloned downstream of the luciferase reporter gene in pLUC-luc. (**B**) pLUC-luc vector containing XIAP/3′-UTR-wt or XIAP/3′-UTR-mut and pGCMV/miR-381 or pGCMV/miR-NC was co-transfected into HEK-293 cells, and cell lysates were prepared after 48 hours and measured for luciferase activity, which was normalized to Renilla luciferase activity. (**C**) Western blot detection of XIAP protein expression in the stably transfected TE10 and TE11 cells. GAPDH was used as an internal control. Each experiment was performed at least in triplicate. $^{**}P<0.01$ vs control.
Abbreviations: miR-381, microRNA-381; XIAP, X-linked inhibitor of apoptosis protein; wt, wild-type; mut, mutant; NS, nonsignificant; NC, negative control.

direct target of miR-381. As far as is known, this is the first report to elucidate the mechanism behind the regulation of radiosensitivity of ESCC by miR-381, suggesting that miR-381 downexpression plays a critical role in the malignant biological behavior of ESCC by inducing XIAP.

miRNAs, which are evolutionarily conserved RNAs with 21–23 nucleotides, regulate posttranscriptional gene expression by binding to complementary sequences in the 3′-UTR and have been increasingly shown to act as tumor suppressors or oncogenes.[9,10] Currently, numerous studies have shown that miRNAs play an important role in the carcinogenesis, progression, and prognosis of ESCC. miR-127, miR-98, miR-145, and miR-153 were reported to be aberrantly downregulated, and miR-1288, miR-183, and miR-17-92 were upregulated in ESCC.[11–17] Moreover, Meng et al showed that overexpression of miR-202 promoted proliferation and migration of human ESCC by inhibiting laminin alpha 1-mediated FAK-PI3K-Akt signaling.[18] Other miRNAs

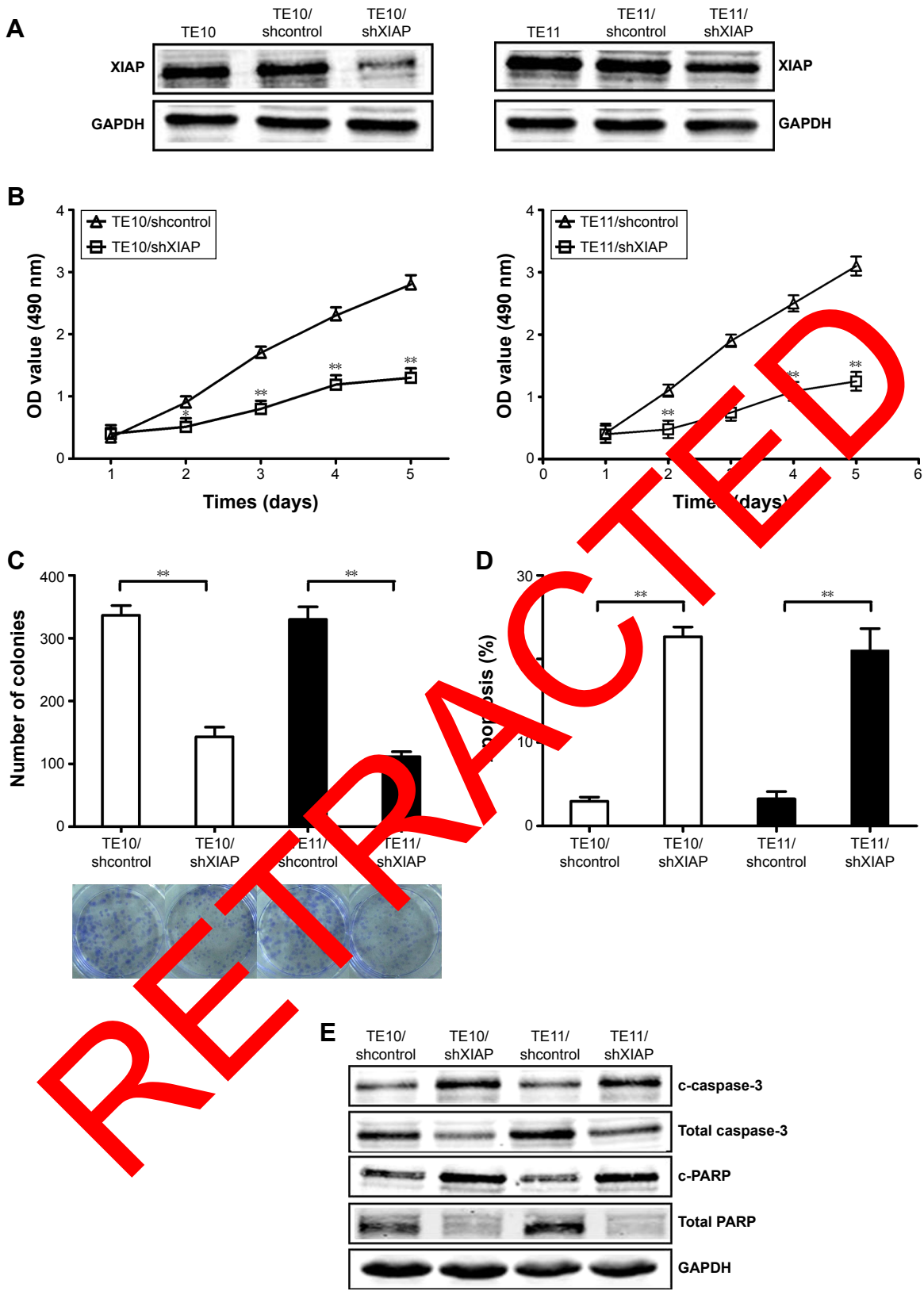

Figure 5 Effects of XIAP knockdown on growth, colony formation, and apoptosis in ESCC cells.

Notes: (**A**) Western blot of XIAP protein expression in TE10 and TE11 cells stably transfected with pGLV3/shXIAP and pGLV3/shcontrol, respectively. GAPDH was used as an internal control. (**B**) MTT analysis of growth in TE10 and TE11 cells stably transfected with pGLV3/shXIAP and pGLV3/shcontrol, respectively. (**C**) Colony formation assay was performed. (**D**) Flow cytometric detection of apoptosis in TE10 and TE11 cells stably transfected with pGLV3/shXIAP and pGLV3/shcontrol, respectively. (**E**) Western blot detection of c-caspase-3, total caspase-3, c-PARP, and total PARP proteins in the stably transfected TE10 and TE1. GAPDH was used as an internal control. Each experiment was performed at least in triplicate. *$P<0.05$ and **$P<0.01$ vs control.

Abbreviations: XIAP, X-linked inhibitor of apoptosis protein; ESCC, esophageal squamous cell carcinoma; OD, optical density.

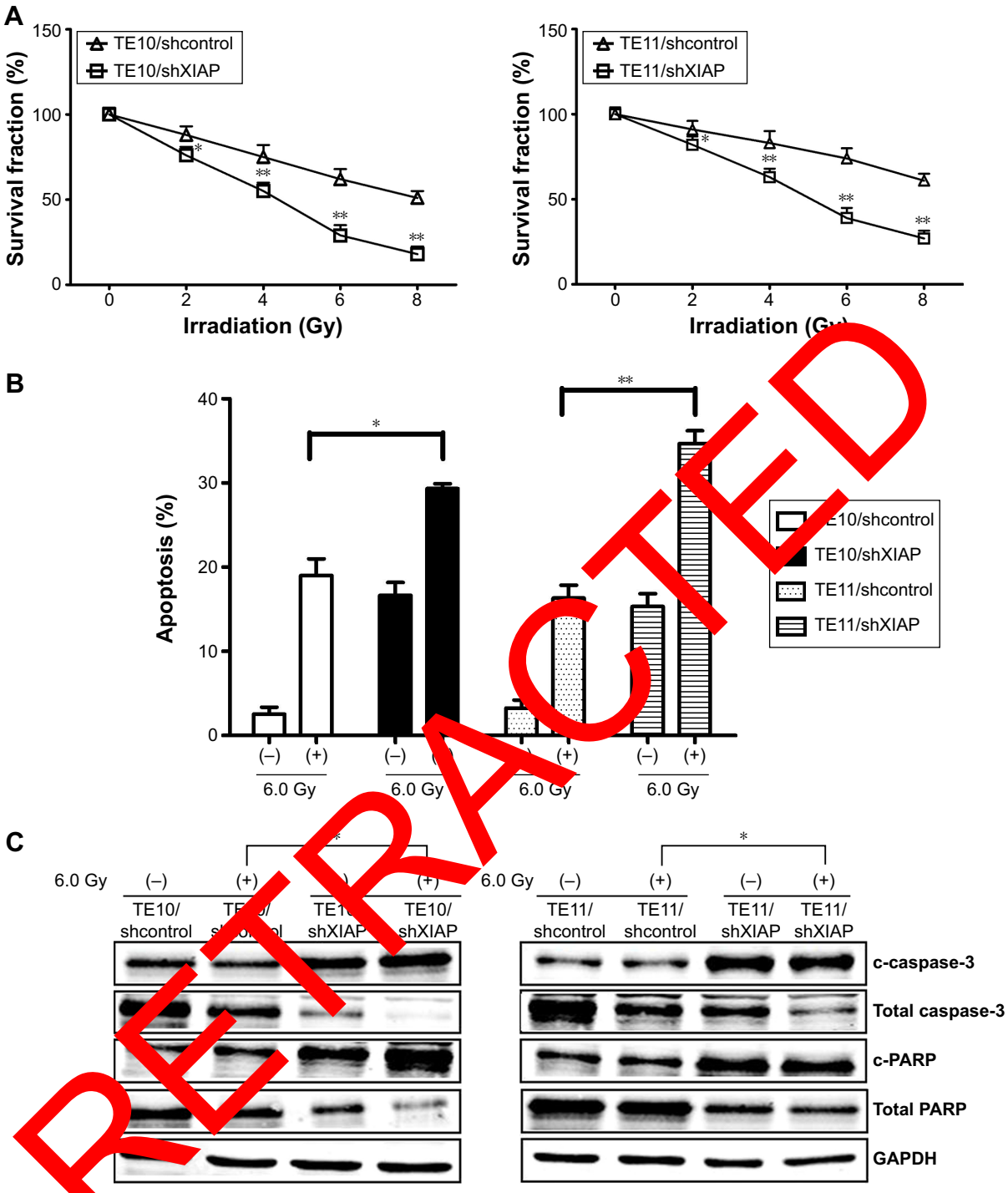

Figure 6 Effect of XIAP knockdown on ESCC radiosensitivity.

Notes: (**A**) Radiosensitization by expression of XIAP was based on clonogenic cell survival assays. Stably transfected TE10 and TE11 were exposed to various doses of radiation prior to plating for clonogenic cell survival. (**B**) Flow cytometric analysis of apoptosis in stably transfected TE10 and TE11 cells treated with (6.0 Gy) or without irradiation. (**C**) Western blot of c-caspase-3, total caspase-3, cleaved c-PARP, and total PARP in stably transfected TE10 and TE11 cells with or without irradiation (6.0 Gy). GAPDH was used as an internal control. Each experiment was performed at least in triplicate. *$P<0.05$ and **$P<0.01$ vs control.

Abbreviations: XIAP, X-linked inhibitor of apoptosis protein; ESCC, esophageal squamous cell carcinoma.

such as miR-153, miR-375, miR-630, and miR-200b could regulate cellular proliferation, migration, invasion, apoptosis, or cell cycle arrest in ESCC.[14,19–21] In addition, serum miRNA expression profile is potentially a useful blood biomarker. Fox example, upregulated expression of serum miR-21 or downregulated expression of serum miR-15a was identified as an unfavorable prognostic factor in ESCC patients.[22,23] These reports suggest that the aberrant miRNAs may be a potential therapeutic target of human ESCC. In a previous study, miR-381 was found to be downregulated and positively correlated

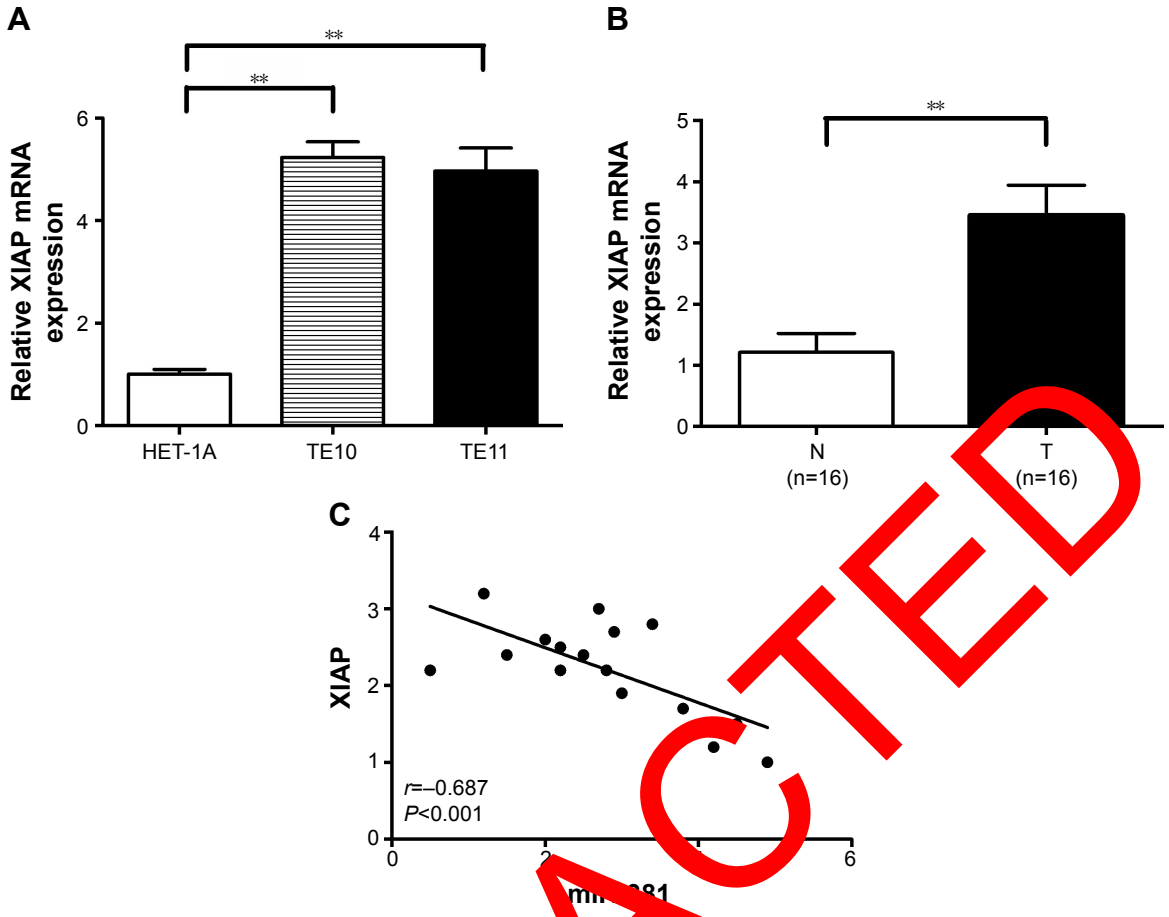

Figure 7 XIAP expression is upregulated in ESCC cells and tissues and inversely correlated with miR-381 expression.

Notes: (**A**) qRT-PCR detection of XIAP mRNA expression in TE10 cells, and HET-1A cells. GAPDH was used as an internal control. (**B**) qRT-PCR detection of XIAP mRNA expression in 16 paired ESCC tissues and adjacent normal tissues. GAPDH was used as an internal control. (**C**) Statistical analysis reveals an inverse correlation between relative miR-381 and XIAP mRNA expression level in ESCC tissues (n=16; $r=-0.687$; $P<0.001$). Corresponding *P*-values analyzed by Spearman correlation test are indicated. $^{**}P<0.01$ vs control.

Abbreviations: T, ESCC tissues; N, adjacent normal tissues; XIAP, X-linked inhibitor of apoptosis protein; ESCC, esophageal squamous cell carcinoma; miR-381, microRNA-381; qRT-PCR, quantitative real-time polymerase chain reaction.

with radiosensitivity in ESCC.[8] However, the mechanisms behind the upregulation of radiosensitivity by miR-381 are presently unclear in ESCC. Here, miR-381 expression was found to be downregulated in both ESCC tissues and ESCC cell lines. Functional analyses further demonstrated that re-expression of miR-381 could inhibit growth, reduce colony formation, and enhance apoptosis in ESCC cells. For years, radioresistance remains a major problem in the treatment of ESCC. Poor prognosis in ESCC patients may be attributed to the presence of an inherently radioresistant cell line.[24] Recently, many miRNAs were found to be associated with radioresistance.[12,25,26] Therefore, a better understanding of the molecular mechanisms involved in the induction of ESCC radioresistance may help to identify a novel molecular target of radiosensitization. This study investigated the effect of miR-381 downregulation on the radiosensitivity of ESCC cell lines. The results obtained indicated that restoration of miR-381 expression enhanced the sensitivity of ESCC to irradiation by inducing irradiation-induced apoptosis. Thus, re-expression of miR-381 may be a novel strategy to reverse radioresistance in ESCC.

The majority of miRNAs exert their effect in a sequence-dependent manner by binding directly to diverse mRNA targets. Identifying the target genes for miR-381 may help to better elucidate the molecular mechanisms of ESCC progression and provide a new theoretical basis to further investigate the re-expression of miR-381 as a promising approach for ESCC treatment. Bioinformatics-based prediction indicated that XIAP was a putative direct target of miR-381. To this day, no reports have studied the correlation between XIAP and miR-381 in ESCC. XIAP, which belongs to the inhibitor-of-apoptosis family, is an inhibitor of apoptotic cell death that protects cells by caspase-dependent and caspase-independent mechanisms.[27] For example, XIAP expression was reported

to be significantly increased in the colorectal cancer (CRC) tissues and cell lines, and downregulation of XIAP in CRC cells inhibited tumor cell growth, induced apoptosis, and enhanced chemosensitivity.[28]

In ESCC, it was found that XIAP and NF-kappa B are intensively expressed in ESCC, and the level of XIAP is positively correlated with progression and prognosis of ESCC.[8] Moreover, Park et al showed that the level of XIAP was induced in irradiated radioresistant cells but not in radiosensitive cells.[29] Luciferase assays indicated that miR-381 binds to the 3′-UTR of XIAP mRNA. However, how does XIAP play a role in ESCC radioresistance requires further investigation. In this study, the results showed that upregulated expression of miR-381 downregulated XIAP protein levels in ESCC. Furthermore, miR-381 expression in ESCC tissues was higher than that in adjacent normal tissues and was inversely correlated with XIAP expression. More importantly, knockdown of XIAP by small interfering RNA exerted a similar effect on growth, apoptosis, and radiosensitivity as miR-381 overexpression in ESCC. Taken together, these data suggest that XIAP may be a direct target of miR-381 in ESCC. However, further study is required to clarify the mechanisms by which XIAP induces apoptosis and regulates radiosensitivity in ESCC cells.

Conclusion

The study demonstrated that miR-381 was downregulated in ESCC and restoration of miR-381 inhibited growth, enhanced apoptosis, and increased radiosensitivity in ESCC. Through luciferase activity assay and functional verification, XIAP was shown to be a direct target of miR-381. Further study showed that miR-381 inhibited growth, increased apoptosis, and enhanced radiosensitivity in ESCC cells by targeting XIAP. Thus, this study provided a better understanding of the mechanisms involved in the induction of ESCC radioresistance and might help to facilitate the development of siRNA-based antitumor strategies. Several weaknesses of the study should be noted. First, other miR-381 target mRNAs need to be identified. Second, other existing unprofiled miRNAs, which may provide more value in clinical application, need to be evaluated. Third, there are calls for chromatin immunoprecipitation or other techniques to clarify the exact mechanisms underlying the regulation of XIAP by miR-381.

Acknowledgment

This work was supported by the National Natural Science Foundation of China (81301922 and 81302055).

Disclosure

The authors report no conflicts of interest in this work.

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