MicroRNA-497 Suppresses Proliferation and Induces Apoptosis in Prostate Cancer Cells

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Abstract

MicroRNAs (miRNAs) are a class of endogenously expressed small, non-coding, single-stranded RNAs that negatively regulate gene expression by mainly binding to 3’- untranslated regions (3’UTR) of their target messenger RNAs (mRNAs), which cause blocks of translation and/or mRNA cleavage. Recently, miRNA profiling studies demonstrated the microRNA-497 (miR-497) level to be down-regulated in all prostate carcinomas compared with BPH samples. The purpose of this study was to investigate the potential role of miR-497 in human prostate cancer. Proliferation, cell cycle and apoptosis assays were conducted to explore the potential function of miR-497 in human prostate cancer cells. Results showed that miR-497 suppressed cellular growth and initiated G0/G1 phase arrest of LNCap and PC-3 cells. We also observed that miR-497 increased the percentage of apoptotic cells by increasing caspase-3/7 activity. Taken together, our results demonstrated that miR-497 can inhibit growth and induce apoptosis by caspase-3 activation in prostate cancer cells, which suggest its use as a potential therapeutic target in the future.

Keywords: MiR-497 - prostate cancer - apoptosis - growth reduction

Asian Pacific J Cancer Prev, 14 (6), 3499-3502

Introduction

MicroRNAs (miRNAs) are a class of endogenously expressed small, non-coding, single-stranded RNAs that negatively regulate gene expression by mainly binding to 3’-untranslated region (3’UTR) of their target messenger RNAs (mRNAs) and cause translational repression or mRNA cleavage (Filipwicz et al., 2008). MicroRNAs execute pivotal roles in physiological and pathological processes including development, differentiation, metabolism, immunity, cell proliferation and apoptosis (Bartel et al., 2004; He et al., 2004; Vasudevan et al., 2007). Hundreds of altered expressions of miRNAs are found to be closely associated with the formation, invasion and progression of most kinds of human cancers, and about 50% of miRNAs genes are found to be located in cancer-related genomic regions (Calin et al., 2006). In these processes, miRNAs may function as oncogenes or tumor suppressors, and the former ones are often up-regulated, whereas the latter are down-regulated in cancers.

Prostate cancer (PCA) is the most prevalent malignancy in males and the second significant cancer killer of men in America and Europe (Siegel et al., 2012). Up to now, more than 50 miRNAs are abnormally expressed, leading to alteration in the expression and activity of their targets in PCA, such as miR-21, miR-320, miR-29b and miR-34c (Ribas et al., 2009; Hagman et al., 2010; Hsieh et al., 2012; Ru et al., 2012). Recently, miRNAs profiling studies demonstrate that miR-497 level is decreased in all prostate carcinoma samples compared with the BPH samples (Porkka et al., 2007; Watahiki et al., 2011). Several studies showed that the potential functions of miR-497 in human breast cancer (Li et al., 2011; Shen et al., 2012), neuroblastoma (Yadav et al., 2011), cervical cancer (Zheng et al., 2012), gastric cancer (Zhu et al., 2012) and colorectal cancer (Guo et al., 2012). However, no studies about the role of miRNA-497 in prostate cancer have been reported.

In this study, miR-497 mimics were used to determine the impact of miR-497 on the proliferation, cell cycle and apoptosis of prostate cancer cells.

Materials and Methods

Cell lines and culture conditions

Human prostate cancer cell lines LNCap (androgen receptor (AR) positive) and PC-3 (AR negative) were obtained from the Shanghai Institutes for Biological Sciences, Chinese Academy of Sciences and grown in RPMI 1640 medium (Life Technologies) with 10% fetal bovine serum (FBS, Gibco), 100 IU/mL Penicillin and 100 µg/mL Streptomycin in a humidified atmosphere of 5% CO2 at 37 °C.

Reagents

MTT, Formazan, Ribonuclease A and propidium iodide (PI) were obtained from Sigma-Aldrich. Caspase-3/7 assay kit was purchased from Promega. Annexin V-FITC
Apoptosis Detection Kit was obtained from Beyotime Institute of Biotechnology (Jiangsu China). Lipofectamine 2000 reagent was obtained from Life Technologies.

Transfection assay for miRNA Mimics
Pre-miRTM miRNA Precursor Molecule mimicking miR-497 and control non-specific miRNA (Pre-miRTM Negative Control) were purchased from Ambion® Life Technologies. LNCaP and PC-3 cells were added into each well of a 6-well plate and cultured with RPMI 1640 medium with 10% FBS. Pre-miR-497 or negative control precursor miRNA and Lipofectamine 2000 reagent were diluted to 100 µL by RPMI 1640 medium without serum and antibiotics, respectively and incubated for 5 minutes at room temperature; then gently combined and incubated for 20 minutes. Subsequently, 200 µL of the complexes were added to each well. After 6 hours of incubation, culture medium was replaced by RPMI-1640 with 10% FBS, and all cells were incubated at 37 °C in a CO₂ incubator for 48 hours prior to further experiments.

Cell proliferation assay
After 48 hours transfection, Cells with various concentrations of miR-497 mimics were trypsinized and counted, respectively. Cells (3,000 cells/well) were plated in each well of 96-well plates in triplicate and incubated at 37 °C for 72 hours. MTT Formazan was added and used to detect cell proliferation. The spectrophotometric absorbance of each sample was measured at 490 nm. The growth inhibition rate was calculated using the following equation: growth inhibiton rate = [the mean optical density (OD) of controls - the mean OD of mimics]/the mean OD of controls. For growth curve assay, Cells were seeded in 24-well plates at a density of 1×10⁴ cells per well. Viable cell numbers in triplicate were determined at 24, 48 and 72 hours.

Colony formation assay
Colony formation assays were performed using LNCaP and PC-3 cells transfected with miRNA-497 mimics and negative control precursor miRNA at 48 hours of post-transfection. Cells were plated and grown at 37 °C in a 5% CO₂ incubator for 14 days. At the end of the experiment, colonies were stained with 0.1% crystal violet. The colony numbers of LNCaP and PC-3 cells were counted. Each bar showed the mean and standard derivation of triplicate samples.

Cell cycle analysis
LNCaP and PC-3 cells were transfected with miRNA-497 or negative control precursor miRNA. At 48 hours of post-transfection, cells were harvested and centrifuged at 1,200 rpm for 5 minutes and washed twice in phosphate buffered saline (PBS). Subsequently, cells were fixed in 70% ethanol at -20°C for overnight. After washing twice with PBS, cells were digested by Ribonuclease A (25 µg/mL) at 37°C for 30 minutes, and stained with PI (25 µg/mL) at 4°C for 1 hour. Cell cycle distribution was analyzed by FACSscan flow cytometer (Becton Dickinson). Caspase-3/7 activity assay
LNCaP and PC-3 cells were transfected with miRNA-497 or negative control precursor miRNA. At 48 hours of post-transfection, cells were trypsinized and plated in 96-well plate for 48 hours incubation. 100 µL of Caspase-Glo 3/7 substrate reagents were added and incubated for 1 hour in the dark. The luminescence of each sample was measured by a plate-reading luminometer.

Apoptosis assay
At 72 hours after miR-497 mimics transfection, cells were trypsinized and washed with PBS, then resuspended in 100 µL of binding buffer. Annexin V staining was accomplished following the product instruction. In brief, 5 µL Annexin V-FITC (2 mg/mL) and 5 µL PI (2 mg/mL) were added and stained for 15 minutes in the dark. The percentage of early and late apoptotic cells was analyzed by flow cytometry.

Statistical analysis
Data were expressed as the means ± standard deviation from at least 3 separate experiments. Statistical analyses were performed using Student’s two-tailed t-test. Difference with P values of <0.05 are considered significant.

Results
miRNA-497 inhibited cell proliferation of prostate cancer cells
To explore the potential role of miR-497 on the proliferation of prostate cancer cells, miR-497 mimics were used to treat with tumor cells at the concentrations of 25, 50 and 100 nmol/L for 72 hours. Cell viability was measured by MTT assay. Compared to negative control, miR-497 significantly inhibited the growth of LNCaP and
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miRNA-497 caused cell cycle arrest of prostate cancer cells

The prostate cancer cells were transfected with miR-497 or negative control precursors to study their effects on cell cycle distribution. After the transfection of miR-497 mimics at the concentration of 100 nmol/L for 48 hours, cell cycle distribution analysis revealed that the percentage of G_0/G_1 phase cells dramatically increased in the miR-497 treatment group (78.70 ± 0.45% in LNCaP cells, 69.55 ± 1.40% in PC-3 cells), which was higher than those in the negative control group (70.41 ± 2.18% in LNCaP cells, 60.28 ± 1.37% in PC-3 cells), and while the proportion of G_2/M phase cells decreased, the percentage of S-phase cells was not significantly altered (Figure 2). These data suggested that miR-497 could initiate G_0/G_1 phase arrest in prostate cancer cells.

miRNA-497 induced apoptosis and caspase-3/7 activities in prostate cancer cells

We further investigated the effect of miR-497 on apoptosis. LNCaP and PC-3 cells were transfected with 100 nmol/L of miR-497 mimics for 72 hours. Flow cytometry analysis demonstrated that the percentage of early apoptosis (1.52% for negative control and 9.91% for miR-497 mimics) in LNCaP cells and the percentage of late apoptosis (0.93% for negative control and 7.72% for miR-497 mimics) in PC-3 cells were increased by miR-497 mimics, compared to the negative control. These results suggested that miR-497 could act as an apoptosis inducer in prostate cancer cells in vitro (Figure 3). To analyze the molecular mechanism of miR-497 mimics on apoptosis, caspase-3/7 activities were examined in prostate cancer cells. The results showed that caspase-3/7 activities were significantly increased in the miR-497 mimics-transfected group, compared with negative control. These data demonstrate that miRNA-497 could induce apoptosis through increasing caspase-3/7 activities (Figure 4).

Discussion

Increasing evidence suggests that miRNAs play a critical role in carcinogenesis and cancer progression (Lu et al., 2005). miRNAs, a class small regulatory RNA molecules that repress gene expression of their mRNA targets in a sequence specific manner, have been identified as key regulators in a wide variety of oncogenic processes, such as cell proliferation, angiogenesis, cellular differentiation, invasion and metastasis, and can function as either tumor suppressors or oncogenes (Kefas et al., 2008; Sun et al., 2010; Zhang et al., 2010).

In this study, our data for the first time have revealed that miR-497 greatly inhibited cellular growth and induced apoptosis and caused G_0/G_1 cell cycle arrest of prostate cancer cells.
The previous studies provided several set of information on the effect of miR-497 on inhibiting cell viability and inducing apoptosis in several different other cancer cell lines. Shen et al reported that miR-497 induced apoptosis of breast cancer cells by targeting Bcl-w (Shen et al., 2012). Zheng et al also reported that miR-497 simultaneously inhibits protein levels of three members of the ERK pathway, RAF1, MEK1 and ERK1 in Hela cells (Zheng et al., 2012). Guo, et al and Luo, et al showed that miR-497 could target the insulin-like growth factor 1 receptor (IGF-1R) and had a tumor-suppressive role in human colorectal and cervical cancer (Guo et al., 2012; Luo et al., 2013). miR-497 maybe have a tumor suppressive role in prostate cancer cells by targeting MAPK, IGF-1R or other signaling pathways, which we will prove them next step.

In this present study, miR-497 caused G_1/G_0 cell cycle arrest in LNCaP and PC-3 cells. The previous data showed that miR-497 have been reported to cooperatively regulate a number of targets, including CDK6, CARD10 and CDC27 leading to regulation of cell proliferation in colon cancer cells (Linsley et al., 2007). We will validate the cell cycle effects induced by miR-497 to explain its mechanism as a tumor suppressor. Caspase-3 protein is a member of the cysteine-aspartic acid protease family. Sequential activation of caspases plays a central role in the execution-phase of cell apoptosis. Caspase-3 cleaves and activates caspasas-6 and -7; and the protein itself is processed and activated by caspases-8, -9 and -10. Our results showed miR-497 increased the caspase-3/7 activities in LNCaP and PC-3 cells. We should analyze the exact mechanisms of miR-497 on apoptosis by Real time PCR and Western blot analysis in the future.

In summary, our results demonstrated that miR-497 induced cell growth inhibition, cell cycle arrest and apoptosis in LNCaP and PC-3 cells. In addition, these effects were associated with increased caspase-3/7 activities in both cells. It may be concluded that miR-497 acts as a tumor suppressor by activating caspase-3/7 activities. However, given the fact that each miRNA may regulate many target genes, more studies are needed to investigate targets by miR-497. Therefore, miR-497 could be a promising therapeutic target for prostate cancer treatment in the future.

Acknowledgements

We give special thanks to all the teachers in the Department of Urology, Affiliated Hospital of Hebei for their help and support. The author(s) declare that they have no competing interests.

References

Bartel DP (2004). MicroRNAs: genomics, biogenesis, mechanism, and function. Cell, 116, 281-97.
Calin GA, Croce CM (2006). MicroRNA signatures in human cancers. Nat Rev Cancer, 6, 857-66.
Filipowicz W, Bhattacharyya SN, Sonenberg N (2008). Mechanisms of post-transcriptional regulation by microRNAs: are the answers in sight? Nat Rev Genet, 9, 102-14.
Guo ST, Jiang CC, Wang GP, et al (2013). MicroRNA-497 targets insulin-like growth factor 1 receptor and has a tumour suppressive role in human colorectal cancer. Oncogene, 32, 1910-20.
Hagman Z, Larne O, Edsjo A, et al (2010). miR-34c is downregulated in prostate cancer and exerts tumor suppressive functions. Int J Cancer, 127, 2768-76.
He L, Hannon GI (2004). MicroRNAs: small RNAs with a big role in gene regulation. Nat Rev Genet, 5, 522-31.
Hsieh IS, Chang KC, Tsai YT, et al (2013). MicroRNA-320 suppresses the stem cell-like characteristics of prostate cancer cells by down-regulating the Wnt/beta-catenin signaling pathway. Carcinogenesis, 34, 530-8.
Kefas B, Godlewski J, Comeau L, et al (2008). microRNA-7 inhibits the epidermal growth factor receptor and the Akt pathway and is down-regulated in glioblastoma. Cancer Res, 68, 3566-72.
Li D, Zhao Y, Liu C, et al (2011). Analysis of MiR-195 and MiR-497 expression, regulation and role in breast cancer. Clin Cancer Res, 17, 1722-30.
Linsley PS, Schelter J, Burchard J, et al (2007). Transcripts targeted by the microRNA-16 family cooperatively regulate cell cycle progression. Mol Cell Biol, 27, 2240-52.
Lu J, Geitz G, Miska EA, et al (2005). MicroRNA expression profiles classify human cancers. Nature, 435, 834-8.
Luo M, Shen D, Zhou X, Chen X, Wang W (2013). MicroRNA-497 is potential prognostic marker in human cervical cancer and functions as a tumor suppressor by targeting the insulin-like growth factor 1 receptor. Surgery, 12, 751-9.
Porkka KP, Pleifffer MJ, Waltering KK, et al (2007). MicroRNA expression profiling in prostate cancer. Cancer Res, 67, 6130-5.
Ribas J, Ni X, Haffner M, et al (2009). miR-21: an androgen receptor-regulated microRNA that promotes hormone-dependent and hormone-independent prostate cancer growth. Cancer Res, 69, 7165-9.
Ru P, Steele R, Newhall P, et al (2012). miRNA-29b suppresses prostate cancer metastasis by regulating epithelial-mesenchymal transition signaling. Mol Cancer Ther, 11, 1166-73.
Shen L, Li J, Xu, L, et al (2012). miR-497 induces apoptosis of breast cancer cells by targeting Bcl-w. Exp Ther Med, 3, 475-80.
Siegel R, Naishadham, D, Jemal A (2012). Cancer statistics. CA Cancer J Clin, 62, 10-29.
Sun H, Li QW, Lv XY, et al (2010). MicroRNA-17 post-transcriptionally regulates polycystic kidney disease-2 gene and promotes cell proliferation. Mol Biol Rep, 37, 2951-8.
Vasudevan S, Tong Y, Steitz JA (2007). Switching from repression to activation: microRNAs can up-regulate translation. Science, 318, 1931-4.
Watahiki A, Wang Y, Morris J, et al (2011). MicroRNAs associated with metastatic prostate cancer. PLoS One, 6, e24950.
Yadav S, Pandey A, Shukla A, et al (2011). miR-497 and miR-302b regulate ethanol-induced neuronal cell death through BCL2 protein and cyclin D2. J Biol Chem, 286, 37347-57.
Zhang J, Yang Y, Yang T, et al (2010). microRNA-22, downregulated in hepatocellular carcinoma and correlated with prognosis, suppresses cell proliferation and tumourigenicity. Br J Cancer, 103, 1215-20.
Zheng D, Radziszewska A, Woo P (2012). MicroRNA 497 modulates interleukin 1 signalling via the MAPK/ERK pathway. FEBS Lett, 586, 4165-72.
Zhu W, Zhu D, Lu S, et al (2012). miR-497 modulates multidrug resistance of human cancer cell lines by targeting BCL2. Med Oncol, 29, 384-91.