

# miR-429 promotes the proliferation of non-small cell lung cancer cells via targeting DLC-1

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Received April 19, 2015; Accepted June 17, 2016

DOI: 10.3892/ol.2016.4904

**Abstract.** The microRNA (miR)-200 family has been demonstrated to be associated with the tumorigenesis and progression of multiple types of human cancer, including non-small cell lung cancer (NSCLC). As a member of the miR-200 family, miR-429 was recently identified to have an oncogenic role in NSCLC. However, the role of miR-429 in NSCLC growth as well as the underlying mechanism remains to be fully elucidated. In the present study, NSCLC cell line H1229 was transfected with miR-429 mimic or inhibitor, respectively. It was observed that overexpression of miR-429 led to a significant increase in NSCLC cell proliferation, while knockdown of miR-429 suppressed the proliferation of H1229 cells. Bioinformatic prediction suggested that deleted in liver cancer 1 (DLC-1), a tumor suppressor in NSCLC, was a putative target gene of miR-429. Therefore, a luciferase reporter assay was performed and confirmed that miR-429 was able to bind the 3'-untranslated region of DLC-1 mRNA in H1229 cells. Furthermore, overexpression of miR-429 inhibited the protein expression of DLC-1, while knockdown of miR-429 promoted the protein expression of DLC-1 in NSCLC H1229 cells. In addition, overexpression of DLC-1 not only inhibited H1229 cell proliferation, but also additionally reversed the promoting effect of miR-429 overexpression on H1229 cell proliferation. Based on these findings, the present study suggests that miR-429 may have an oncogenic role in the regulation of cell proliferation via direct inhibition of DLC-1 protein expression in NSCLC cells. Therefore, miR-429 may present a putative therapeutic target for the treatment of NSCLC growth.

## Introduction

Lung cancer is the most common cause of cancer-associated mortality for men and women globally, while non-small cell lung cancer (NSCLC) is responsible for ~90% of lung cancer cases (1). Although surgical resection, radiotherapy and chemotherapy have led to improvements in the treatment of NSCLC, the prognosis of patients remains poor (1,2). Therefore, development of effective therapeutic targets for the treatment of NSCLC is required.

MicroRNAs (miRs), a type of small non-coding RNA, are able to bind the 3'-untranslated region (UTR) of mRNAs, leading to mRNA degradation or inhibition of gene translation (3). It has been demonstrated that miRs act as critical regulators in tumorigenesis, and deregulation of specific miRs has been observed in various types of human cancer (4,5). Lang *et al* (6) reported that the expression of miR-429 was frequently increased in NSCLC compared with normal lung tissues, and it was additionally upregulated in NSCLC cell lines compared with normal lung cells. It was also demonstrated that miR-429 had a promoting role in the regulation of NSCLC cell proliferation, migration and invasion, and three targets of miR-429 were identified: Phosphatase and tensin homolog (PTEN), Ras association domain-containing protein 8 (RASSF8) and TIMP metalloproteinase inhibitor 2 (TIMP2) (6). However, as a single miR may have numerous targets (3), whether other targets of miR-429 may also be involved in the development of NSCLC remains to be elucidated.

Deleted in liver cancer 1 (DLC-1), is a Rho GTPase activating protein, and a member of the rhoGAP family of proteins, which have a role in the regulation of small GTP-binding proteins as well as cell processes involved in cytoskeletal changes (7,8). Recently, DLC-1 was observed to be frequently downregulated, either by genomic deletion or DNA methylation, in a variety of types of cancer, including lung, breast, prostate, kidney, colon, uterus, ovary and stomach (9). Yuan *et al* (10) reported that overexpression of DLC-1 caused a significant inhibition in cell proliferation and colony formation *in vitro*, and abolished tumorigenicity *in vivo*, suggesting that DLC-1 may be a tumor suppressor in NSCLC. However, the regulatory mechanism of DLC-1 in NSCLC cells, as well as its association with miR-429, remains to be fully elucidated.

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**Key words:** non-small cell lung cancer, microRNA, proliferation, deleted in liver cancer 1

The present study aimed to investigate the role of miR-429 in the regulation of NSCLC cell migration and invasion, as well as the underlying mechanism involving DLC-1.

## Materials and methods

**Cell culture.** The human NSCLC cell line H1229 was obtained from the Cell bank of Central South University (Changsha, China). Cells were cultured in Dulbecco's modified Eagle's medium (DMEM; Thermo Fisher Scientific, Inc., Waltham, MA, USA) supplemented with 10% fetal bovine serum (FBS, Thermo Fisher Scientific, Inc.) at 37°C in an atmosphere of 5% CO<sub>2</sub>.

**RNA extraction and reverse transcription-quantitative polymerase chain reaction (RT-qPCR).** Total RNA was extracted using TRIzol® Reagent (Thermo Fisher Scientific, Inc.). For miR detection, a TaqMan MicroRNA Reverse Transcription kit (Thermo Fisher Scientific, Inc.) was used to convert RNA into complementary DNA, according to the manufacturer's protocol. qPCR was subsequently performed by using an All-in-One™ miRNA qRT-PCR Detection kit (GeneCopoeia, Inc., Rockville, MD, USA) on an Applied Biosystems 7500 thermocycler (Thermo Fisher Scientific, Inc.). The U6 gene was used as an internal reference. For mRNA detection, RT-qPCR analysis was performed using the SYBR Green qPCR Master Mix (Thermo Fisher Scientific, Inc.) and specific primers synthesized by Sangon Biotech Co., Ltd. (Shanghai, China). The specific primer sequences were as follows: DLC-1 forward, 5'-CCACGGACCTCCCATCTTC-3' and reverse, 5'-GCTGTGCATACTGGGGGAA-3'; GAPDH forward, 5'-ACAACCTTGGTATCGTGAAGG-3' and reverse, 5'-GCCATCACGCCACAGTTTC-3'. The PCR steps were 95°C for 5 min, followed by 40 cycles of denaturation at 95°C for 15 sec and annealing/elongation step at 60°C for 30 sec. The relative expression was analyzed by the 2<sup>-ΔΔC<sub>q</sub></sup> method (11).

**Western blotting.** Cells were solubilized in cold radioimmuno-precipitation assay lysis buffer (Beyotime Biotechnology Inc., Shanghai, China). Proteins (20 μg per lane) were separated by 12% SDS-PAGE, and transferred onto a polyvinylidene difluoride (PVDF) membrane, which was subsequently blocked with Tris-buffered saline with Tween-20 containing 5% milk at room temperature for 3 h. The PVDF membrane was subsequently incubated with rabbit polyclonal anti-DLC-1 antibody (1:100 dilution; catalog no. ab126257) and rabbit monoclonal GAPDH antibody (1:100 dilution; catalog no. EPR16891) (both Abcam, Cambridge, UK) at room temperature for 3 h. Following washing with phosphate-buffered saline with Tween-20 three times, the membrane was incubated with mouse monoclonal anti-rabbit horseradish peroxidase-conjugated secondary antibody (1:5,000 dilution; catalog no. ab99702; Abcam) at room temperature for 40 min. Detection was performed using an enhanced chemiluminescence kit (Pierce; Thermo Fisher Scientific, Inc.). The relative protein expression was analyzed by Image-Pro plus software 6.0 (Media Cybernetics, Inc., Rockville, MD, USA).

**Transfection.** The scramble miRNA mimic, miR-429 mimic and miR-429 inhibitor were generated by GenePharma Co.,

Ltd. (Shanghai, China). Lipofectamine™ 2000 (Thermo Fisher Scientific, Inc.) was used to perform transfection according to the manufacturer's protocol. Briefly, the materials used to transfect the cells (scramble miR mimic, miR-429 mimic, miR-429 inhibitor, pcDNA3.1-DLC 1 plasmid and blank pcDNA3.1 vector) were diluted with serum-free DMEM, respectively. Lipofectamine 2000 was also diluted with serum-free DMEM. The diluted Lipofectamine 2000 was added into the diluted plasmid, or miRNA mimic, or inhibitor, and incubated for 20 min at room temperature, and subsequently added to the H1229 cells at ~70% confluence in a 6-well plate. Subsequently, the cells were incubated at 37°C in an atmosphere of 5% CO<sub>2</sub> for 6 h. Following incubation, the medium in each well was replaced by the DMEM supplemented with 10% FBS, and cultured for 24 h at 37°C prior to performance of the following assays.

**3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide (MTT) assay.** Cell viability was determined using an MTT assay according to the manufacturer's protocol. Briefly, cells were suspended in 0.2 ml DMEM at a concentration of 5,000 cells/well and incubated overnight in 96-well plates. Absorbance at 429 nm was measured using a microplate reader (Molecular Devices, LLC, Sunnyvale, CA, USA).

**Bioinformatics analysis.** TargetsScan Human 7.0 online software (www.targetsScan.org) was used to predicate the potential target genes of miR-429. 'Human' was selected as the species, and 'miR-429' was entered.

**Dual luciferase reporter assays.** A QuikChange Site-Directed Mutagenesis kit (Agilent Technologies, Inc., Santa Clara, CA, USA) was used to generate a mutant type (MUT) 3'-UTR of DLC-1, according to the manufacturer's protocol. The wild-type (WT) or MUT of DLC-1 3'-UTR was inserted into the psiCHECK™ 2 vector (catalog no. C8021; Promega Corporation, Madison, WI, USA), generating psiCHECK™ 2-DLC-1 or psiCHECK™ 2-MUT DLC-1, respectively. H1229 cells were cultured to approximately 70% confluence, and subsequently transfected with psiCHECK™ 2-DLC-1 or psiCHECK™ 2-MUT DLC-1, with or without 100 nM miR-429 mimic. Following transfection at 37°C for 48 h, the luciferase activities were determined on an LD400 luminometer (Beckman Coulter, Inc., Brea, CA, USA). *Renilla luciferase* activity was normalized to firefly luciferase activity.

**Statistical methods.** The results are expressed as the mean ± standard deviation of at least three independent experiments. Statistical analysis was performed by one-way analysis of variance. Statistical analysis was performed with Graph-Pad Prism version 5 (GraphPad Software, Inc., La Jolla, CA, USA). P<0.05 was considered to indicate a statistically significant difference.

## Results

**miR-429 promotes the proliferation of NSCLC cells.** Initially, the present study investigated the role of miR-429 in mediating the proliferation of NSCLC cells. H1229 cells were transfected with scramble miR mimic, miR-429 mimic or miR-429 inhibitor, respectively. Following transfection,

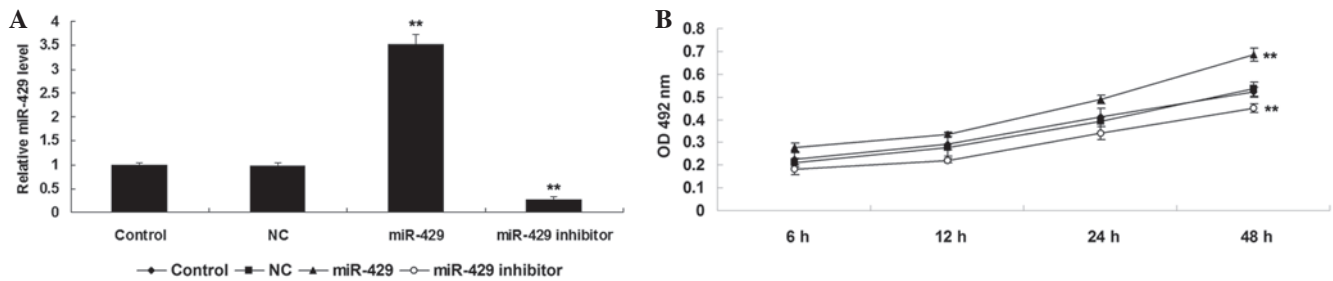


Figure 1. (A) Reverse transcription-quantitative polymerase chain reaction was used to determine the miR-429 level in H1229 cells transfected with miR-429 mimic, miR-429 inhibitor or scramble miR mimic as a NC. (B) An 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide assay was performed to examine cell proliferation in each group. Non-transfected H1229 cells were used as a control. \*\*P<0.01 vs. control. miR, microRNA; NC, negative control; OD, optical density.

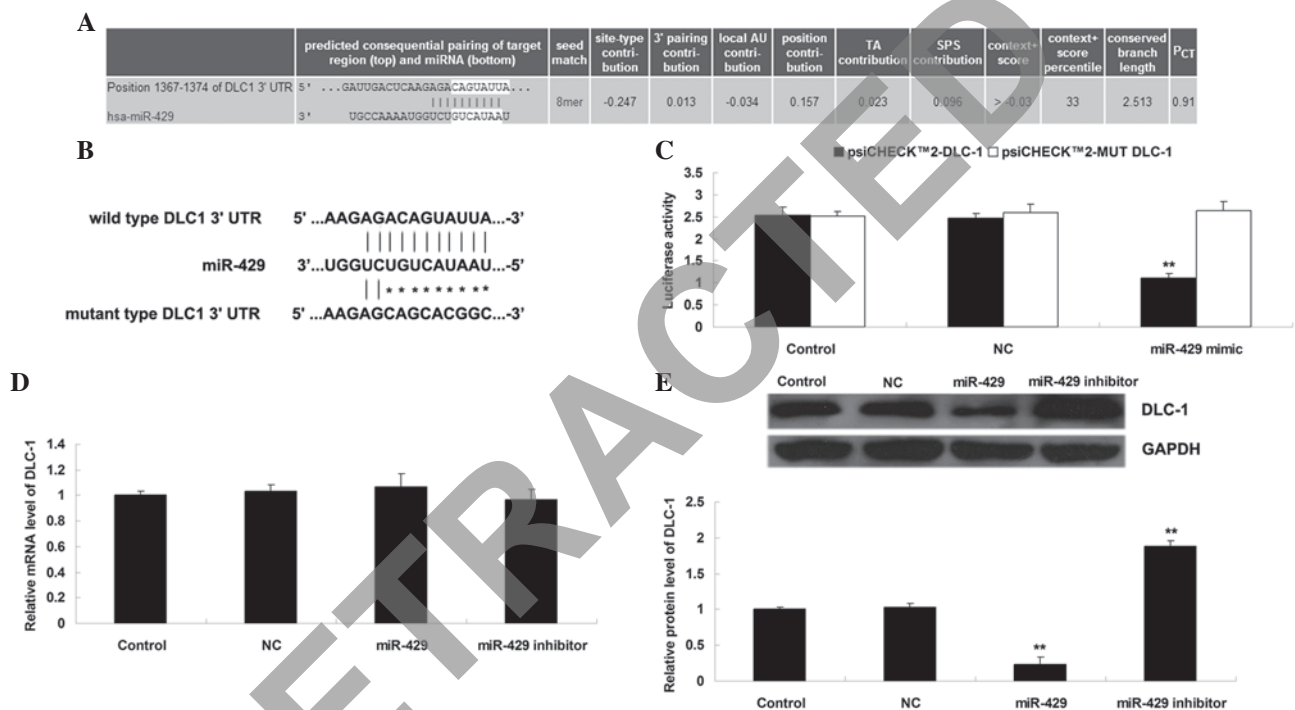


Figure 2. (A) Bioinformatic analysis revealed that the targeting association between miR-429 and DLC-1 is evolutionarily conserved. (B) The seed sequences for miR-429 at the wild type or mutant type 3'UTR of DLC-1 are shown. (C) Luciferase reporter assay was performed to clarify whether DLC-1 was a target gene of miR-429. The luciferase activity was reduced only in non-small cell lung cancer H1229 cells co-transfected with miR-429 mimic and wild type DLC-1 3'UTR, but unchanged in other groups. \*\*P<0.01 vs. control. (D) Reverse transcription-quantitative polymerase chain reaction and (E) western blotting were used to determine the mRNA and protein expression levels of DLC-1 in H1229 cells transfected with miR-429 mimic, miR-429 inhibitor or scramble miR mimic as a NC. Glyceraldehyde-3-phosphate dehydrogenase was used as an internal reference. Non-transfected H1229 cells were used as a control. \*\*P<0.01 vs. control. miR, microRNA; DLC-1, deleted in liver cancer 1; UTR, untranslated region; NC, negative control.

RT-qPCR was performed to examine the expression level of miR-429 in H1229 cells in each group. As shown in Fig. 1A, transfection with miR-429 mimic enhanced the expression of miR-429 in H1229 cells compared to the control group (P<0.01), while transfection with miR-429 inhibitor reduced the miR-429 expression in H1229 cells compared to the control group (P<0.01). Subsequently, an MTT assay was performed to investigate the cell proliferation in each group. As shown in Fig. 1B, overexpression of miR-429 markedly promoted H1229 cell proliferation (P<0.01), while knockdown of miR-429 inhibited tumor cell proliferation, compared to the control group (P<0.01). Therefore, the results of the present study suggest that miR-429 may have an oncogenic role in the regulation of NSCLC cell proliferation.

*DLC-1 is a novel target of miR-429 in NSCLC cells.* Bioinformatic analysis was performed to predict the putative target genes of miR-429. DLC-1 was predicated to be a target gene of miR-429 and the putative seed sequences for miR-429 at the 3'-UTR of DLC-1 were evolutionarily conserved (Fig. 2A). WT or MUT DLC-1 3'-UTR was inserted into the psiCHECK<sup>TM</sup> 2 vector, generating Luc-DLC-1 3'-UTR or Luc-MUT DLC-1 3'-UTR, respectively (Fig. 2B). Subsequently, a luciferase reporter assay was performed to clarify whether DLC-1 was a target gene of miR-429, and the results of the present study demonstrated that the luciferase activity was reduced only in H1229 cells co-transfected with Luc-DLC-1 3'-UTR and miR-429 mimic (P<0.01), and was not altered in other groups (P>0.05) (Fig. 2C). These data indicate that miR-429 may

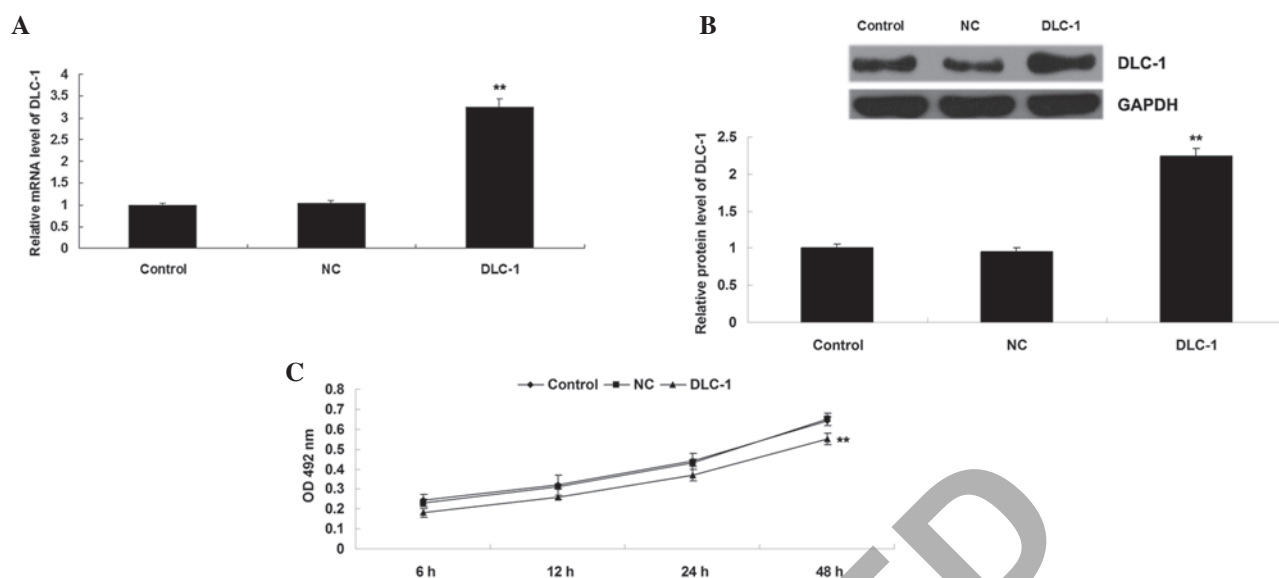


Figure 3. (A) Reverse transcription-quantitative polymerase chain reaction and (B) western blotting assays were performed to examine the mRNA and protein levels of DLC-1 in H1229 cells transfected with DLC-1 plasmid or blank vector, respectively. (C) Cell proliferation was subsequently examined by 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide assay in each group. Non-transfected H1229 cells were used as a control. \*\* $P < 0.01$  vs. control. DLC-1, deleted in liver cancer 1; NC, negative control; GAPDH, glyceraldehyde-3-phosphate dehydrogenase; OD, optical density.

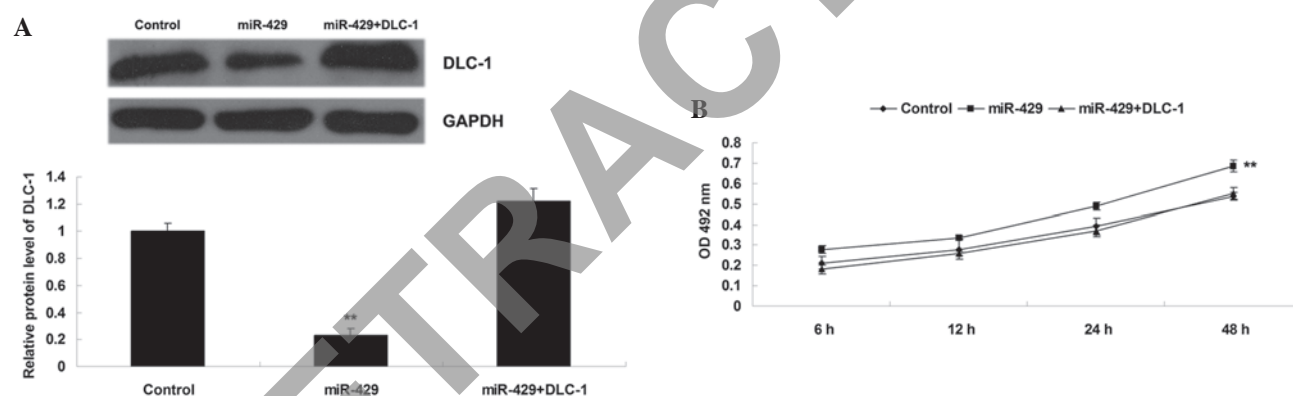


Figure 4. (A) Western blotting was performed to examine the protein level of DLC-1 in H1229 cells transfected with miR-429 mimic, or co-transfected with miR-429 mimic and DLC-1 plasmid, respectively. (B) Cell proliferation was subsequently examined by conducting a 3-(4,5-dimethylthiazol-2-yl)-2,5-diphenyltetrazolium bromide assay in each group. Non-transfected H1229 cells were used as a control. \*\* $P < 0.01$  vs. control. DLC-1, deleted in liver cancer 1; miR, micro RNA; GAPDH, glyceraldehyde-3-phosphate dehydrogenase; OD, optical density.

directly bind the 3'-UTR of DLC-1. As miRs generally negatively regulate the expression of their target genes, it was also investigated whether the mRNA and protein levels of DLC-1 were negatively mediated by miR-429 in H1229 cells. As shown in Fig. 2D and E, overexpression of miR-429 decreased the protein (but not mRNA) levels of DLC-1 ( $P < 0.01$ ), while knockdown of miR-429 increased the protein (but not mRNA) levels of DLC-1 in H1229 cells ( $P < 0.01$ ). Therefore, the present study demonstrates that miR-429 negatively mediates the protein expression of DLC-1 via directly binding the 3'-UTR of DLC-1 mRNA in NSCLC H1229 cells.

**DLC-1 inhibits the proliferation of NSCLC H1229 cells.** The present study also transfected H1229 cells with DLC-1 plasmid or blank vector as a negative control. Following transfection, the protein level of DLC-1 was determined in H1229 cells in each group. As shown in Fig. 3A and B, transfection with DLC-1 plasmid significantly upregulated the protein level of DLC-1

compared to the control group ( $P < 0.01$ ), while transfection with blank vector exerted no effect on the protein expression of DLC-1 in H1229 cells ( $P > 0.05$ ). Subsequently, an MTT assay was performed, which identified that overexpression of DLC-1 significantly suppressed H1229 cell proliferation compared to the control group ( $P < 0.01$ ) (Fig. 3C), indicating that DLC-1 may act as a tumor suppressor in NSCLC.

**DLC-1 is involved in miR-429-mediated proliferation in NSCLC H1229 cells.** The present study also determined whether DLC-1 was a downstream effector of miR-429 in H1229 cells. DLC-1 plasmid was introduced into the H1229 cells overexpressing miR-429. As shown in Fig. 4A, transfection with DLC-1 plasmid significantly upregulated the protein level of DLC-1 when compared with that in H1229 cells transfected with miR-429 mimic ( $P < 0.01$ ). Subsequently, an MTT assay was performed, which identified that overexpression of DLC-1 significantly reversed the promoting



effect of miR-429 upregulation on H1229 cell proliferation ( $P < 0.01$ ) (Fig. 4B). These data suggest that DLC-1 is involved in miR-429-mediated proliferation in NSCLC H1229 cells, and that the promoting role of miR-429 in the regulation of NSCLC cell proliferation is potentially due to inhibition of DLC-1 expression.

## Discussion

In the present study, it was observed that overexpression of miR-429 led to a significant increase in NSCLC cell proliferation, while knockdown of miR-429 enhanced the proliferation of NSCLC H1229 cells. The present study additionally confirmed that DLC-1 is a target gene of miR-429, and the protein expression of DLC-1 was negatively regulated by miR-429 in NSCLC H1229 cells. Furthermore, overexpression of DLC-1 not only inhibited H1229 cell proliferation, but also reversed the promoting effect of miR-429 overexpression on H1229 cell proliferation. Therefore, the promoting role of miR-429 in the regulation of NSCLC cell proliferation is potentially due to inhibition of DLC-1 expression.

Dual roles of miR-429 have been suggested in a variety of types of human cancer, including ovarian (12), colorectal (13-15), esophageal (16) and gastric cancer (17,18), as well as osteosarcoma (19). Yoneyama *et al* (20) demonstrated that the expression level of miR-429, accompanied with miR-200a/b, was significantly increased in endometrioid endometrial carcinoma (ECC) compared to adjacent normal endometrial tissues. Furthermore, miRs-429, -200a and -200b may directly target tumor suppressor PTEN, and therefore act as onco-miRs in ECC (20). Knockdown of miR-429 was also observed to inhibit proliferation by targeting p27<sup>Kip1</sup> in human prostate cancer cells (21). By contrast, miR-429 may act as a tumor suppressor in certain cancer types. Song *et al* (22) reported that miR-429 was frequently downregulated in pancreatic ductal adenocarcinoma (PDAC) tissues and cell lines, and lower miR-429 expression in PDAC tissues significantly correlated with shorter survival of PDAC patients. In addition, overexpression of miR-429 inhibited PDAC cell growth via targeting TANK-binding kinase 1 (22). Ye *et al* (23) reported that miR-429 inhibited the migration and invasion of breast cancer cells via inhibition of zinc finger E-box binding homeobox 1 and Crk-like expression.

Deregulation of miR-429 has been demonstrated in lung cancer. Zhu *et al* (24) reported that the serum and tissue levels of miR-429 were frequently downregulated in early stage NSCLC, and the levels of miR-429 were associated with poor overall survival of NSCLC patients. By contrast, Lang *et al* (6) reported that the expression of miR-429 was frequently upregulated in NSCLC compared with normal lung tissues, and its expression level was also increased in NSCLC cell lines compared with normal lung cells. Accordingly, the expression of miR-429 in NSCLC may be specific dependent on the stage. It was also observed that overexpression of miR-429 in A549 NSCLC cells significantly promoted cell proliferation, migration and invasion, whereas inhibition of miR-429 inhibits these effects, potentially via targeting PTEN, RASSF8 and TIMP2 (6). In the present study, it was also demonstrated that miR-429 had a promoting effect on the proliferation of NSCLC H1229 cells.

The present study also identified DLC-1 as a novel target of miR-429 in NSCLC H1229 cells. DLC-1 serves as a

GTPase-activating protein (GAP) for members of the Rho family of GTPases, particularly Rho A-C and cell division cycle 42 (7). DLC-1 has been demonstrated to act as a tumor suppressor in various types of human cancer, where it relies on the RhoGAP activity and steroidogenic acute regulatory-related lipid transfer domain of DLC-1, as well as its focal adhesion localization (9). Furthermore, the suppressive role of DLC-1 in lung cancer has been reported by several studies. Yuan *et al* (10) reported that DLC-1 was frequently downregulated in NSCLC tissues compared to normal lung tissues, potentially due to the aberrant DNA methylation in the promoter of the DLC-1 gene. Furthermore, it was observed that overexpression of DLC-1 inhibited the growth of NSCLC *in vitro* and *in vivo* (10). Healy *et al* (25) also reported that DLC-1 suppressed NSCLC growth and invasion by RhoGAP-dependent and independent mechanisms. In the present study, it was demonstrated that overexpression of DLC-1 significantly inhibited NSCLC H1229 cell proliferation. Furthermore, it was observed that DLC-1 acted as a downstream effector in miR-429-mediated H1229 cell proliferation, suggesting a novel mechanism through which miR-429 may regulate NSCLC growth.

In conclusion, the present study demonstrates that miR-429 has inhibitory effects on NSCLC cell proliferation via inhibition of DLC-1 expression. Therefore, miR-429 may become a putative therapeutic target for the treatment of NSCLC growth. Future research should investigate the regulatory mechanism of the miR-429/DLC-1 axis in NSCLC growth *in vivo*.

## Acknowledgements

The present study was supported by the Hunan Province Natural Science Foundation of China (grant no., 14JJ2029).

## References

1. Torre LA, Bray F, Siegel RL, Ferlay J, Lortet-Tieulent J and Jemal A: Global cancer statistics, 2012. *CA Cancer J Clin* 65: 87-108, 2015.
2. Pilkington G, Boland A, Brown T, Oyee J, Bagust A and Dickson R: A systematic review of the clinical effectiveness of first-line chemotherapy for adult patients with locally advanced or metastatic non-small cell lung cancer. *Thorax* 70: 359-367, 2015.
3. Ambros V: The functions of animal microRNAs. *Nature* 431: 350-355, 2004.
4. Bienertova-Vasku J, Sana J and Slaby O: The role of microRNAs in mitochondria in cancer. *Cancer Lett* 336: 1-7, 2013.
5. Bouyssou JM, Manier S, Huynh D, Issa S, Roccaro AM and Ghobrial IM: Regulation of microRNAs in cancer metastasis. *Biochim Biophys Acta* 1845: 255-265, 2014.
6. Lang Y, Xu S, Ma J, Wu J, Jin S, Cao S and Yu Y: MicroRNA-429 induces tumorigenesis of human non-small cell lung cancer cells and targets multiple tumor suppressor genes. *Biochem Biophys Res Commun* 450: 154-159, 2014.
7. Kim TY, Vigil D, Der CJ and Juliano RL: Role of DLC-1, a tumor suppressor protein with RhoGAP activity, in regulation of the cytoskeleton and cell motility. *Cancer Metastasis Rev* 28: 77-83, 2009.
8. Zimonjic DB and Popescu NC: Role of DLC1 tumor suppressor gene and MYC oncogene in pathogenesis of human hepatocellular carcinoma: Potential prospects for combined targeted therapeutics (review). *Int J Oncol* 41: 393-406, 2012.
9. Liao YC and Lo SH: Deleted in liver cancer-1 (DLC-1): A tumor suppressor not just for liver. *Int J Biochem Cell Biol* 40: 843-847, 2008.
10. Yuan BZ, Jefferson AM, Baldwin KT, Thorgeirsson SS, Popescu NC and Reynolds SH: DLC-1 operates as a tumor suppressor gene in human non-small cell lung carcinomas. *Oncogene* 23: 1405-1411, 2004.

11. Livak and Schmittgen: Analysis of relative gene expression data using real-time quantitative PCR and the 2(-Delta Delta C(T)) method. *Methods* 25: 402-408, 2001.
12. Chen J, Wang L, Matyunina LV, Hill CG and McDonald JF: Overexpression of miR-429 induces mesenchymal-to-epithelial transition (MET) in metastatic ovarian cancer cells. *Gynecol Oncol* 121: 200-205, 2011.
13. Sun Y, Shen S, Tang H, Xiang J, Peng Y, Tang A, Li N, Zhou W, Wang Z, Zhang D, *et al*: miR-429 identified by dynamic transcriptome analysis is a new candidate biomarker for colorectal cancer prognosis. *OMICS* 18: 54-64, 2014.
14. Li J, Du L, Yang Y, Wang C, Liu H, Wang L, Zhang X, Li W, Zheng G and Dong Z: MiR-429 is an independent prognostic factor in colorectal cancer and exerts its anti-apoptotic function by targeting SOX2. *Cancer Lett* 329: 84-90, 2013.
15. Sun Y, Shen S, Liu X, Tang H, Wang Z, Yu Z, Li X and Wu M: MiR-429 inhibits cells growth and invasion and regulates EMT-related marker genes by targeting Onecut2 in colorectal carcinoma. *Mol Cell Biochem* 390: 19-30, 2014.
16. Wang Y, Li M, Zang W, Ma Y, Wang N, Li P, Wang T and Zhao G: MiR-429 up-regulation induces apoptosis and suppresses invasion by targeting Bcl-2 and SP-1 in esophageal carcinoma. *Cell Oncol (Dordr)* 36: 385-394, 2013.
17. Liu D, Xia P, Diao D, Cheng Y, Zhang H, Yuan D, Huang C and Dang C: MiRNA-429 suppresses the growth of gastric cancer cells in vitro. *J Biomed Res* 26: 389-393, 2012.
18. Sun T, Wang C, Xing J and Wu D: miR-429 modulates the expression of c-myc in human gastric carcinoma cells. *Eur J Cancer* 47: 2552-2559, 2011.
19. Liu X, Liu Y, Wu S, Shi X, Li L, Zhao J and Xu H: Tumor-suppressing effects of miR-429 on human osteosarcoma. *Cell Biochem Biophys* 70: 215-224, 2014.
20. Yoneyama K, Ishibashi O, Kawase R, Kurose K and Takeshita T: miR-200a, miR-200b and miR-429 are onco-mirs that target the PTEN gene in endometrioid endometrial carcinoma. *Anticancer Res* 35: 1401-1410, 2015.
21. Ouyang Y, Gao P, Zhu B, Chen X, Lin F, Wang X, Wei J and Zhang H: Downregulation of microRNA-429 inhibits cell proliferation by targeting p27Kip1 in human prostate cancer cells. *Mol Med Rep* 11: 1435-1441, 2015.
22. Song B, Zheng K, Ma H, Liu A, Jing W, Shao C, Li G and Jin G: miR-429 determines poor outcome and inhibits pancreatic ductal adenocarcinoma growth by targeting TBK1. *Cell Physiol Biochem* 35: 1846-1856, 2015.
23. Ye ZB, Ma G, Zhao YH, Xiao Y, Zhan Y, Jing C, Gao K, Liu ZH and Yu SJ: miR-429 inhibits migration and invasion of breast cancer cells in vitro. *Int J Oncol* 46: 531-538, 2015.
24. Zhu W, He J, Chen D, Zhang B, Xu L, Ma H, Liu X, Zhang Y and Le H: Expression of miR-29c, miR-93, and miR-429 as potential biomarkers for detection of early stage non-small lung cancer. *PLoS One* 9: e87780, 2014.
25. Healy KD, Hodgson L, Kim TY, Shutes A, Maddileti S, Juliano RL, Hahn KM, Harden TK, Bang YJ and Der CJ: DLC-1 suppresses non-small cell lung cancer growth and invasion by RhoGAP-dependent and independent mechanisms. *Mol Carcinog* 47: 326-337, 2008.