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Down-regulation of Rab10 inhibits hypoxia-induced invasion and EMT in thyroid cancer cells by targeting HIF-1α through the PI3K/Akt pathway

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Rab10, a member of the Rab family, is localized to endocytic compartments and serves as a regulator of intracellular vesicle trafficking. Previous studies mainly paid attention to the role of Rab10 in transport. Recently, Rab10 has been reported to be involved in the progression of various cancers. However, the biological functions of Rab10 in thyroid cancer remain unknown. In this study, we demonstrated that Rab10 was highly expressed in thyroid cancer tissues and cell lines. Down-regulation of Rab10 inhibited hypoxia-induced migration, invasion and epithelial–mesenchymal transition (EMT) of thyroid cancer cells. Moreover, HIF-1α and the PI3K/Akt pathway were involved in the inhibitory effect of Rab10 down-regulation on thyroid cancer cell invasion and EMT induced by hypoxia. Taken together, our study provided further evidence to support the role of Rab10 as a therapeutic target for thyroid cancer.

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I. Introduction

Thyroid cancer is a common type of tumor related to the endocrine system and its incidence has been steadily rising in the past decades.[1–3] This disease mainly originates from follicular cells encompassing a range of differentiation from indolent cancer types (follicular or papillary thyroid cancer) to invasive and lethal cancer types (undifferentiated thyroid cancer).[4] This broad spectrum of development is partly linked to epigenetic dysregulation of genes associated with tumor differentiation, aggressive ability and metastatic potential.[5] Increasing evidence has demonstrated that the epithelial–mesenchymal transition (EMT) process plays a crucial role in cancer invasion and metastasis.[6–8] Therefore, it is desperately needed to explore novel biomarkers related to EMT and investigate the underlying molecular mechanisms for the purpose of facilitating the treatment of thyroid cancer.

The Rab family, belonging to the RAS superfamily of small GTPases, contains more than 60 members.[9,10] These members act as a regulator of intercellular vesicle trafficking, receptor recycling and signal transduction.[11] These processes, in turn, mediate the normal membrane polarity.[12–14] Besides, these Rab GTPases can be activated by distinct types of Rab GEFs and down-regulated by Rab GAPs.[15] Rab10, a member of the Rab family, is an important participant in formation of endoplasmic reticulum, secretion of basement membrane and translocation of glucose transporter type 4.[16–18] Furthermore, Rab10 plays a crucial role in innate immune responses *via* regulating transport of toll-like receptor 4.[19,20] Recently, Rab10 has been demonstrated to be aberrantly expressed in some types of cancers and show biological significance in cancer progression.[21–23] However, the specific role of Rab10 in thyroid cancer remains unknown.

In this study, we demonstrated that Rab10 was elevated in thyroid cancer tissues and cell lines. Down-regulation of Rab10 inhibited hypoxia-induced migration, invasion and EMT of thyroid cancer cells. In addition, we found that Rab10 down-regulation exerted the inhibitory effect on thyroid cancer cells exposed to hypoxia by targeting HIF-1α through the PI3K/Akt pathway.

II Results

Expression of Rab10 is up-regulated in thyroid cancer tissues and cell lines

To investigate the effect of Rab10 on thyroid cancer, we first measured the expression levels of Rab10 mRNA and protein in thyroid cancer tissues and adjacent normal tissues from 42 patients. The results showed that the expression of Rab10 in thyroid cancer tissues was significantly increased at both mRNA and protein levels in comparison with the normal tissues (Fig. 1A and B). The expression of Rab10 was also evaluated in thyroid cancer cell lines. As shown in Fig. 1C and D, Rab10 mRNA and protein levels in WRO and 8505C cell lines were markedly higher than those in the normal thyroid cell line Nthy-ori 3-1.

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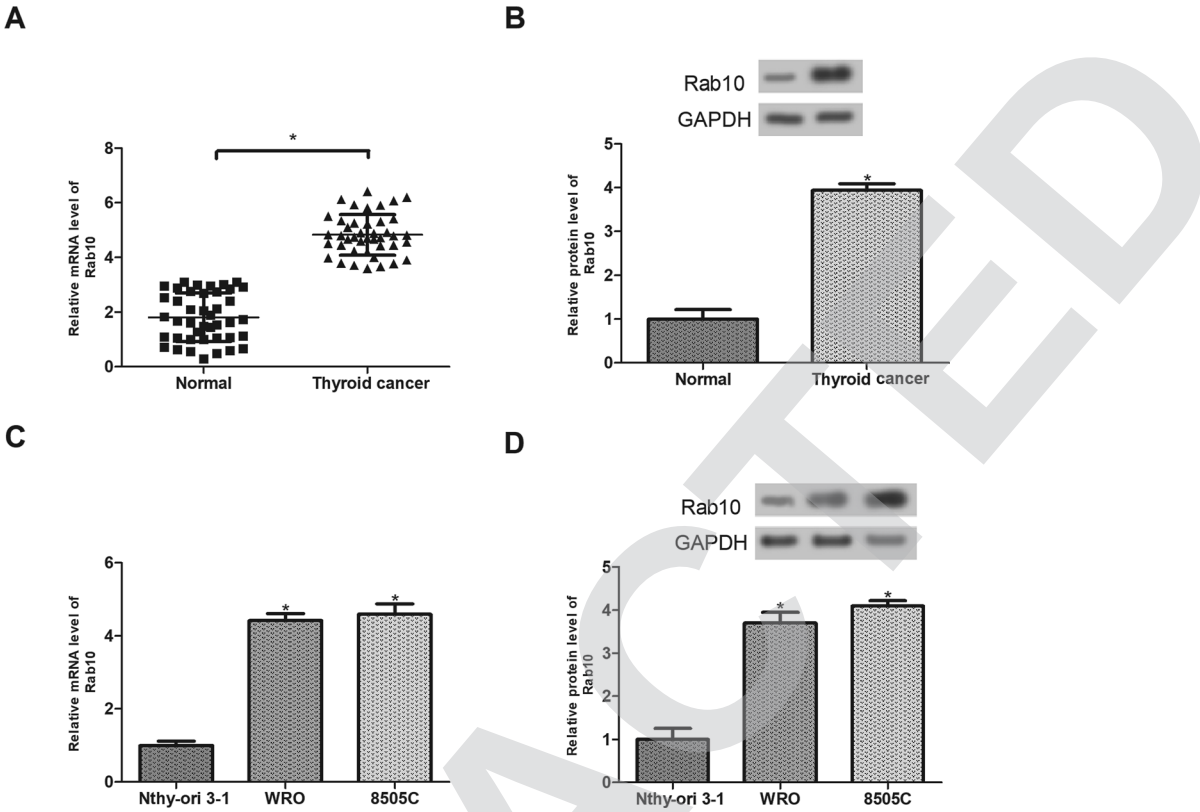

Fig. 1 Expression of Rab10 is up-regulated in thyroid cancer tissues and cell lines. (A and B) RT-PCR and western blot analysis of Rab10 expression in thyroid cancer tissues and adjacent normal tissues. ($n = 42$). (C and D) RT-PCR and western blot analysis of Rab10 expression in thyroid cancer cell lines (WRO and 8505C) and the normal thyroid cell line Nthy-ori 3-1. $n = 3$. *$p < 0.05$.

Down-regulation of Rab10 inhibits the viability of thyroid cancer cells exposed to hypoxia

We first examined the effect of hypoxia on thyroid cancer cell viability. As shown in Fig. 2A and B, no obvious effect on the cell viability was observed after hypoxia exposure for 24 h while the viability was significantly reduced after hypoxia exposure for 48 h. Therefore, WRO and 8505C cells were treated with hypoxia for 24 h in the subsequent experiments.

Next, we decreased the expression of Rab10 in thyroid cancer cells. Down-regulation of Rab10 in WRO and 8505C cells was confirmed by western blot analysis (Fig. 2C and D). Then we detected the effect of Rab10 down-regulation on cell viability under hypoxic conditions. The results showed that the inhibitory effect of Rab10 down-regulation was much stronger on WRO cell viability under hypoxic conditions than those incubated under normoxic conditions (Fig. 2E). Similar results were obtained in 8505C cells (Fig. 2F).

Down-regulation of Rab10 inhibits hypoxia-induced migration, invasion and EMT of thyroid cancer cells

Hypoxia has been demonstrated to induce cancer cell migration and invasion.[24] So we detected the effect of Rab10 down-regulation on hypoxia-induced cell migration and invasion. As shown in Fig. 3A and B, hypoxia remarkably increased the migratory and invasive abilities of WRO cells, which were decreased by Rab10 down-regulation. Similarly, we found that down-regulation of Rab10 inhibited hypoxia-induced migration and invasion of 8505C cells (Fig. 3C and D).

The EMT process plays an essential role in cancer progression and the hypoxic environment can stimulate this process,[6–8,25] so we investigated the effect of Rab10 down-regulation on hypoxia-induced EMT in thyroid cancer cells. As shown in Fig. 3E, the expression of E-cadherin was decreased while the expression of N-cadherin was increased after hypoxia treatment in WRO cells. But the EMT process was reversed by Rab10 down-regulation in WRO cells cultured under hypoxic conditions (Fig. 3E). Similar results were found in 8505C cells (Fig. 3F).

HIF-1α and the PI3K/Akt pathway are involved in the inhibitory effect of Rab10 down-regulation on thyroid cancer cell invasion and EMT induced by hypoxia

HIF-1α is known as a regulator of cancer cell invasion and EMT under hypoxic conditions.[26–29] So, we investigated whether Rab10 down-regulation exerted the inhibitory effect on hypoxia-induced invasion and EMT by regulating the HIF-1α expression. As expected, Rab10 down-regulation decreased hypoxia-induced HIF-1α expression in WRO cells (Fig. 4A). To further confirm the involvement of HIF-1α in hypoxia-regulated invasion and EMT, HIF-1α shRNA was transfected into the WRO cells and the knockdown efficiency was verified by western blot analysis (Fig. 4B). Moreover, the cell invasion assay showed that HIF-1α knockdown inhibited hypoxia-induced invasion of WRO cells

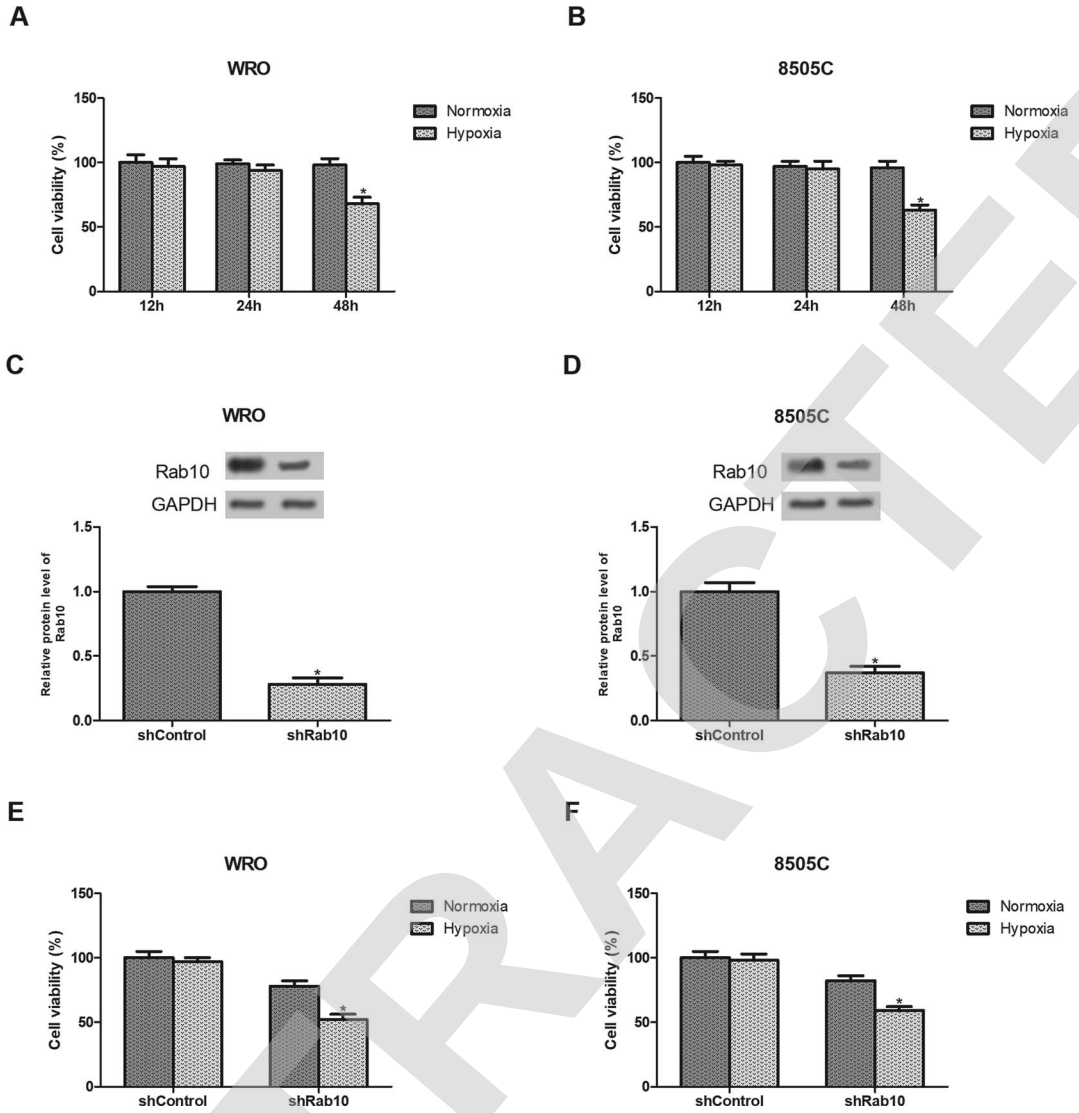

Fig. 2 Down-regulation of Rab10 inhibits the viability of thyroid cancer cells exposed to hypoxia. (A and B) WRO and 8505C cells were cultured under normoxic or hypoxic conditions for indicated times. Cell viability was detected by the MTT assay. (C and D) Rab10 expression levels in WRO and 8505C cells were measured by western blot analysis after transfection of shRab10 or shControl. (E and F) WRO and 8505C cell viability were determined using the MTT assay after transfection and treatment with normoxia or hypoxia. $n = 3$. *$p < 0.05$.

and Rab10 down-regulation enhanced the inhibitory effect (Fig. 4C). We also found that HIF-1α knockdown suppressed hypoxia-induced decrease in E-cadherin expression in WRO cells and the suppressive effect was potentiated by Rab10 down-regulation (Fig. 4D).

Numerous studies have shown that the PI3K/Akt signaling pathway could regulate the levels of HIF-1α.[30,31] Thus, we assumed that Rab10 down-regulation might mediate the expression of HIF-1α *via* the PI3K/Akt pathway. The results showed that hypoxia treatment obviously increased the expression of p-PI3K and p-Akt in WRO cells, but the effect was significantly impaired by Rab10 down-regulation (Fig. 4E and F).

III. Discussion

According to statistics, over 6% of thyroid cancers are characterized by vigorous migratory and invasive capabilities which are considered crucial signs of a lethal outcome.[32,33] Thus, prevention of migration and invasion is a necessity for thyroid cancer therapy.

Rab10, a member of the Rab family, is localized to endocytic compartments and serves as a regulator of intracellular vesicle trafficking.[34] Rab10 deletion could decrease cell adhesion and affect a number of cell functions.[35] Previous studies mainly paid attention to the role of Rab10 in transport. Recently, Rab10 has been reported to be involved in progression of various cancers. For example, Wang *et al.* demonstrated the oncogenic role of Rab10 in hepatocellular cancer and its association with the poor prognosis of hepatocellular cancer patients.[22] Furthermore, Rab10 has been targeted to inhibit cell migration and invasion in osteosarcoma.[23] In this study, we found that Rab10 was highly expressed in thyroid cancer tissues and cell lines, indicating the potential role of Rab10 in thyroid cancer.

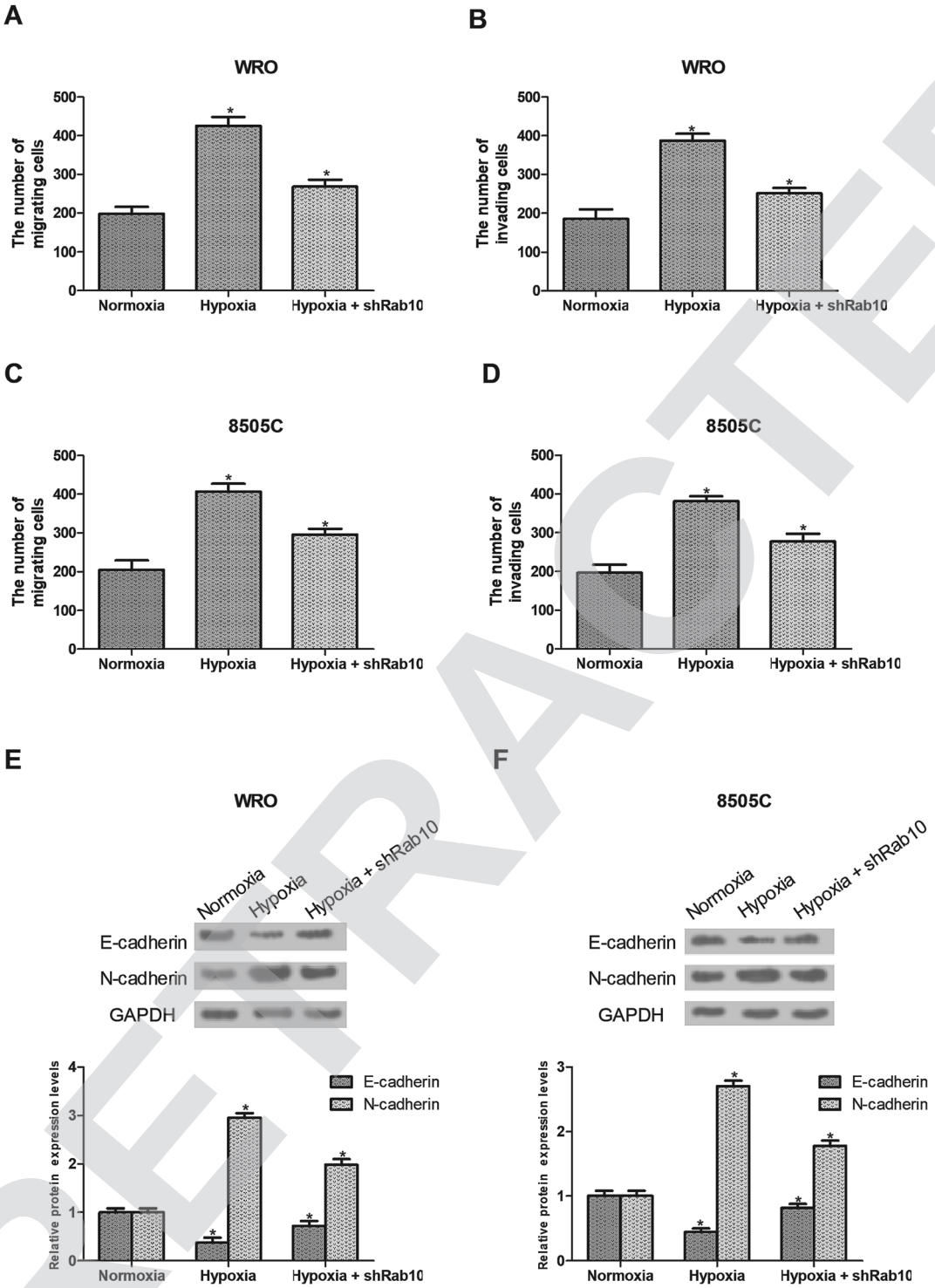

Fig. 3 Down-regulation of Rab10 inhibits hypoxia-induced migration, invasion and EMT of thyroid cancer cells. (A–D) WRO and 8505C cell migration and invasion were detected using the transwell assay. (E and F) The expression levels of E-cadherin and N-cadherin in WRO and 8505C cells were assessed by western blot analysis. $n = 3$. *$p < 0.05$.

The EMT process is an essential step during cancer cell migration and invasion.[6–8] A distinct hallmark of EMT is the loss or reduction of E-cadherin expression.[36] So far, a variety of EMT inducers have been identified and one of the vital factors is hypoxia.[37–41] Tissue hypoxia is caused by the poor development of angiogenic vessels.[42] Under hypoxic conditions, cell morphology will change and subsequently lead to a mesenchymal-like phenotype, which is an obvious feature of the EMT process.[8] In this study, we found that down-regulation of Rab10 inhibited hypoxia-induced migration, invasion and EMT

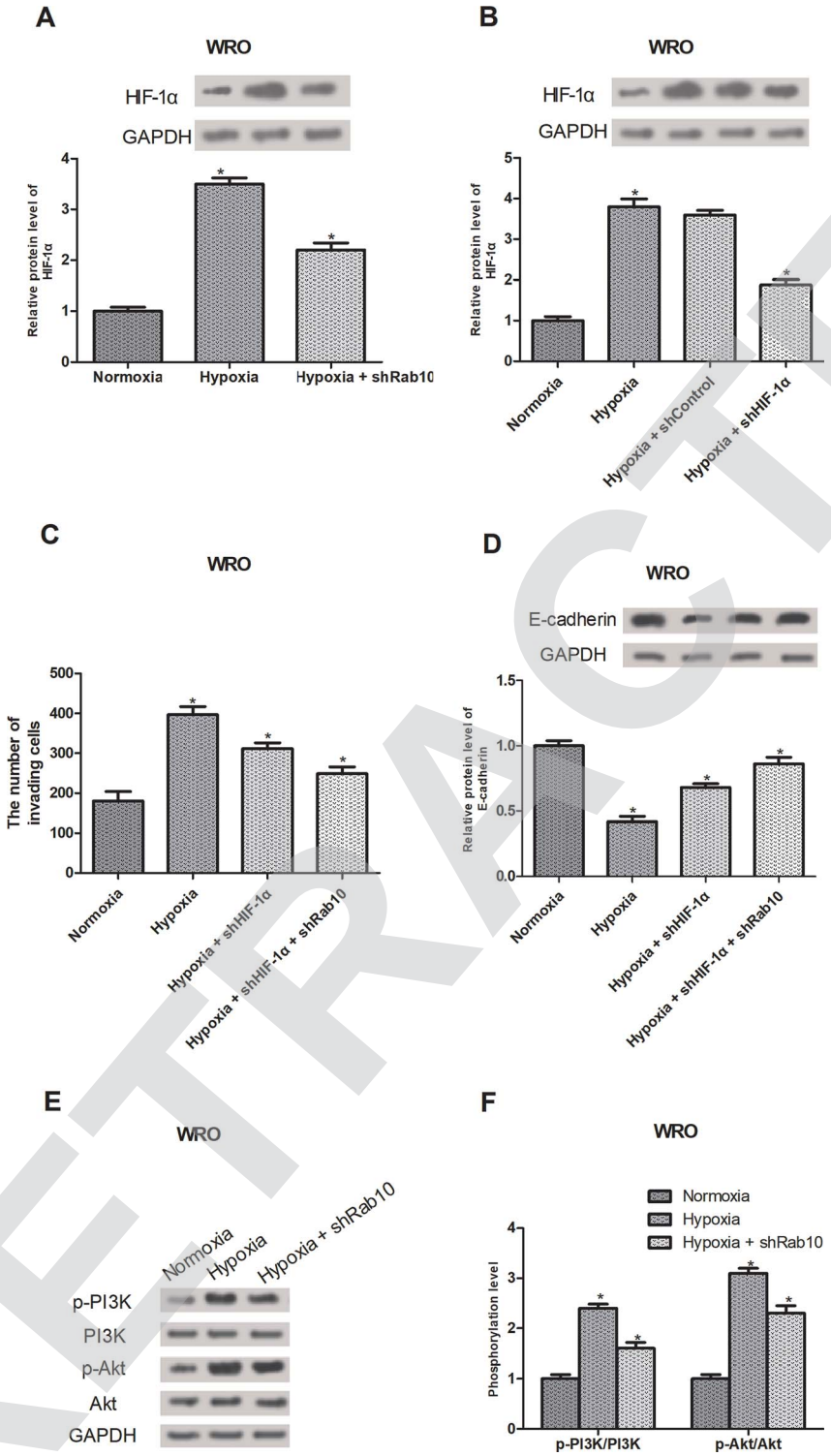

Fig. 4 HIF-1α and the PI3K/Akt pathway are involved in the inhibitory effect of Rab10 down-regulation on thyroid cancer cell invasion and EMT induced by hypoxia. (A and B) Western blot analysis of HIF-1α expression in WRO cells after different treatment. (C) WRO cell invasion was measured using the transwell assay. (D) Western blot analysis of E-cadherin expression in WRO cells. (E) Western blot analysis of the protein expression of p-PI3K, PI3K, p-Akt and Akt in WRO cells. (F) Quantification of the protein expression levels of p-PI3K, PI3K, p-Akt and Akt. $n = 3$. *$p < 0.05$.

of thyroid cancer cells. All these observations suggested that Rab10 down-regulation blocked thyroid cancer cell migration and invasion by suppressing EMT under hypoxic conditions.

HIF-1α, a signal transcription factor, is a hallmark of cell invasion and a crucial regulator of the EMT process.[26,27,43] HIF-1α could be induced upon hypoxia, which will influence the

expression and activity of some important transcription factors and subsequently cause inhibition of E-cadherin in cancer cells.[27–29] In this study, we found that Rab10 down-regulation decreased hypoxia-induced HIF-1α expression in thyroid cancer cells; HIF-1α knockdown inhibited hypoxia-induced decrease in E-cadherin expression and the inhibitory effect was enhanced by Rab10 down-regulation. Our findings suggested that Rab10 down-regulation blocked hypoxia-induced EMT in thyroid cancer cells by suppressing HIF-1α expression.

Increasing evidence has demonstrated that the PI3K/Akt pathway could mediate HIF-1α expression in cancer cells. For example, Sun *et al.* reported that PI3K inhibitors significantly prevented HIF-1α induction under hypoxic conditions in prostate cancer.[44] In our study, we found that hypoxia treatment markedly elevated the expression of p-PI3K and p-Akt in thyroid cancer cells and this effect was reversed after Rab10 down-regulation. These results indicated that down-regulation of Rab10 inhibited hypoxia-induced EMT in thyroid cancer cells by reducing HIF-1α expression through regulation of the PI3K/Akt signaling pathway.

In conclusion, we demonstrated that Rab10 was highly expressed in thyroid cancer tissues and cell lines. Down-regulation of Rab10 inhibited hypoxia-induced migration, invasion and EMT of thyroid cancer cells. Moreover, HIF-1α and the PI3K/Akt pathway were involved in the inhibitory effect of Rab10 down-regulation on thyroid cancer cell invasion and EMT induced by hypoxia. Taken together, our study provided further evidence to support the role of Rab10 as a therapeutic target for thyroid cancer.

IV. Materials and methods

Patients and tissue samples

This study was approved by the Ethics Committee of Huaihe Hospital of Henan University (Kaifeng, China). A total of 42 patients with thyroid cancer participated in the study and provided informed consent. None of the patients received any adjuvant therapies before surgery. All thyroid cancer tissues and corresponding adjacent normal tissues were collected from the patients and then stored at −80 °C for future experiments. This study was approved by the Ethics Committee of Huaihe Hospital of Henan University, and written informed consent was obtained from all patients.

Cell lines and cell culture

Human thyroid cancer cell lines (WRO and 8505C) and thyroid follicular epithelial cell line Nthy-ori 3-1 were purchased from the American Type Culture Collection (ATCC, Manassas, VA, USA). All cell lines were cultured in RPMI-1640 (Gibco, Rockville, MD, USA) containing 10% fetal bovine serum (FBS; Gibco) and 100 U ml^{-1} penicillin/streptomycin and incubated at 37 °C in a standard humidified atmosphere with 5% CO_2.

To induce hypoxia, cells were seeded in a six-well plate and continuously gassed with 5% CO_2 and 1% O_2 (balanced with N_2) at 37 °C in a sealed incubator (Thermo Fisher Scientific, Waltham, MA, USA) for different time. Control cells were cultured under a normoxic condition (5% CO_2 and 21% O_2) at room temperature.

Quantitative real-time polymerase chain reaction (qRT-PCR)

Total RNA was isolated from tissues or cells using TRIzol reagent (Invitrogen, Carlsbad, CA, USA). An equal amount of sample was reversely transcribed using M-MLV Reverse Transcriptase (Invitrogen). The RT-PCR was performed using a PTC-200 PCR system (Bio-Rad, Hercules, CA, USA) under the following condition: 95 °C for 10 min, 40 cycles of 95 °C for 10 s, 55 °C for 10 s and 72 °C for 10 min. The primers were: Rab10, 5′-TTTCACACCATCACAACCTCC-3′ (forward) and 5′-GGTACAACTCTTTTGTCGTCCATA-3′ (reverse); GAPDH, 5′-TGACTTCAACAGCGACACCCA-3′ (forward) and 5′-CACCCTGTTGCTGTAGCCAAA-3′ (reverse). GAPDH was used as an internal control. The relative expression was calculated using the $2^{-\Delta\Delta C_t}$ method.

Western blot analysis

Tissues or cells were lysed with lysis buffer and the protein lysates were separated by 12% SDS-PAGE and then transferred onto PVDF membranes (Millipore, Billerica, MA, USA). After blocking in 5% non-fat milk for 2 h, the membranes were incubated with the primary antibodies against Rab10 (1:1000), E-cadherin (1:1000), N-cadherin (1:1000), HIF-1α (1:1000), p-PI3K (1:2000), PI3K (1:2000), p-Akt (1:2000), Akt (1:2000) and GAPDH (1:2000). Subsequently, the membranes were washed and incubated with appropriate secondary antibodies. All antibodies were obtained from Invitrogen. The immunoreactive bands were detected using an enhanced chemiluminescence kit (Pierce, Rockford, IL, USA) and quantified using the Quantity One software.

Cell transfection

The shRNA against Rab10 or HIF-1α was purchased from GeneCopoeia (Rockville, MD, USA). A non-specific shRNA was used as a negative control. All the shRNA sequences were as follows: shRab10, 5′-GCTACAGCGAGTACGTTTACCT-3′; shHIF-1α, 5′-CCTATATCCCAATGGATGA-3′; shControl, 5′-GCTACAGCGAGTACGTTTACCT-3′. Cells were transfected with shRab10, shHIF-1α or shControl using Lipofectamine 2000 reagent (Invitrogen) according to the manufacturer's instructions. The transfection efficiency was confirmed by western blot analysis.

Cell viability assay

The effect of hypoxia on cell viability was determined by the MTT assay. In brief, cells (1×10^4 per well) were exposed to hypoxia for indicated times in a 96-well plate. Then MTT solution (5 mg ml^{-1}; Sigma, St. Louis, MO, USA) was added to each well and cells were further cultured for 4 h at 37 °C. Subsequently, the culture medium was removed and DMSO (Sigma) was added. The optical density was measured at 570 nm using a microplate reader.

Transwell assay

Transwell chambers were used to assess cell migration and invasion. 24-well plates with Matrigel-free inserts were for cell

migration and those with Matrigel-coated inserts were for cell invasion. Briefly, the upper chamber was filled with serum-free medium and 2×10^4 cells were added. Culture medium with 10% FBS was added to the lower chamber as a chemoattractant. After incubation for 24 h, cells on the upper surface of the insert were removed and cells on the lower surface of the insert were fixed and stained with 0.1% crystal violet. The number of cells in five random fields was counted under a microscope (400×).

Statistical analysis

Data were collected from three independent experiments and shown as means ± standard deviation (SD). Statistical analysis was performed using SPSS 19.0 software. Student's *t*-test or one-way ANOVA was used for the comparison between different groups. Differences were considered statistically significant when the p value was less than 0.05.

Conflicts of interest

The authors declare that they have no conflicts of interest.

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