Effect of long non-coding RNA AOC4P on gastrointestinal stromal tumor cells

Jin-Chen Hu1,3,*
Quan Wang1,*
Li-Xin Jiang1
Li Cai3
Hui-Yuan Zhai1
Zeng-Wu Yao1
Meng-Lai Zhang1
Ye Feng1

1Department of Gastrointestinal Surgery, The Affiliated Yantai Yuhuangding Hospital of Qingdao University, Yantai, China; 2Department of Gastrointestinal and Anal Surgery, The First Hospital of Jilin University, Changchun, China; 3Department of Pathology, The Affiliated Yantai Yuhuangding Hospital of Qingdao University, Yantai, China; 4Department of Gastrointestinal Colorectal and Anal Surgery, China-Japan Union Hospital of Jilin University, Changchun, China

*These authors contributed equally to this work

Correspondence: Ye Feng
Department of Gastrointestinal Colorectal and Anal Surgery, China-Japan Union Hospital of Jilin University, No 126 Xintai Street, Changchun 130033, Jilin, China
Tel +86 0431 818 7561
Email fengye20178@126.com

Objective: In this research, we explored the effect of long non-coding RNA (lncRNA) AOC4P on gastrointestinal stromal tumor (GIST) cells.

Materials and methods: The expression of IncRNA AOC4P in tissues was detected by real-time PCR (RT-PCR). The epithelial–mesenchymal transition (EMT)-related proteins in tissues were analyzed by Western blot. The experimental model included negative control group (CN), silence AOC4P group (si AOC4P), and silence negative control group (si CT). RT-PCR, MTT, Scratch, Transwell, and Annexin V-FITC methods were used to detect the expression of IncRNA AOC4P, cell proliferation, cell migration ability, cell invasion ability, and apoptosis, respectively. The EMT-related proteins including TGF-β, ZEB1, Vimentin, Snail, and E-cadherin were analyzed by Western blot.

Results: The expression of IncRNA AOC4P and the expression of EMT-related proteins in high-risk GISTs were higher than that in low- and intermediate-risk GISTs (P<0.05). It was revealed that cell proliferative migration and invasive ability in si AOC4P group was decreased than that in CN and si CT group (P<0.05), and cell apoptosis in si AOC4P group was higher than that in CN group. The results of Western blot demonstrated that the expression of TGF-β1, ZEB1, Vimentin, and Snail in si AOC4P group were lower than that in si CT and CN group (P<0.05), and the expression of E-cadherin in si AOC4P group was higher than that in si CT and CN group (P<0.05).

Keywords: AOC4P, epithelial–mesenchymal transition, gastrointestinal stromal tumors, long non-coding RNA

Introduction

Gastrointestinal stromal tumor (GIST) was the most common mesenchymal tissue tumors in the alimentary canal.1,2 It was demonstrated that the mortality of GIST was high in human beings, and it mostly occurred in old-aged patients.2 The clinical behaviors of GIST patients include gastrointestinal hemorrhage, enclosed mass in abdomen, and pain of belly, associated with the primary tissues and lump growth.3–5 In addition, unceasing reports have demonstrated that surgical resection for localized primary GIST was the curative mainstay of therapy.6,7 Nevertheless, it still faces great challenges that the risk of recurrence is as high as ~40% and the clinicopathologic features vary greatly.8 Therefore, it is of great significance to find an effective method for the treatment of GIST.

In recent years, long non-coding RNA (lncRNA) has attracted great attention from researchers.9,10 It was demonstrated that the abnormal expression of IncRNA was greatly associated with the occurrence of malignant tumors. The results suggested that IncRNA which participated in epigenetic regulation could regulate cell proliferation, apoptosis, infiltration, and transformation, thereby controlling and regulating tumors. Some IncRNAs including metastasis-associated lung adenocarcinoma transcript 1,
highly upregulated in liver cancer, H19, and HOX antisense intergenic RNA, were found by high-throughput screening method, and numerous investigations pointed that IncRNA has the potential to be the therapeutic target of tumors.12

In previous studies, researchers had investigated the differences of IncRNA in gastric carcinoma including GIST and the normal tissues, and five of IncRNAs (TINCR, CCAT2, AOC4P, BANCR, and LINC00857) were significantly elevated in gastric carcinoma.13 TINCR, CCAT2, and BANCR in gastric carcinoma have been documented in previous studies.14–18 These results demonstrated that TINCR upregulates the expression of SP1, followed by mediating the expression of KLF2 mRNA to regulate cell proliferation and apoptosis. It is also found that CCAT2 is associated with lymph gland and distant metastasis and that NF-KB as the unfavorable prognosis symbol affects cell apoptosis through NF-KB pathway.17 It has also been documented that IncRNA containing amine oxidase copper containing four pseudogenes (AOC4P) can inhibit the transformation of hepatoma carcinoma cells through the degradation of the vimentin.19,20 In addition, the investigations have demonstrated that the AOC4P inhibits the degradation of UHRF1 and promotes the occurrence of colorectal carcinoma. Therefore, AOC4P as one of IncRNAs exerts important effects on tumors. Epithelial–mesenchymal transition (EMT) is the morphological transformation of epithelial-like cancer cells to an elongated mesenchymal phenotype.20 During EMT, cancer cells stop expressing the adhesion protein, including epithelial E-cadherin, and increase the expression of mesenchymal phenotype markers, including vimentin and Snail.21 Currently, the roles of IncRNA AOC4P influencing GIST cells to undergo EMT is not widely known or studied.

The targeted therapies of GIST were tyrosine kinase KIT and PDGFRA.22–24 In 2003, Heinrich et al25 further elaborated the role of PDGFRA in the pathogenesis of GIST that were negative for the expression of c-KIT. These research studies demonstrated that GISTs are predominantly c-KIT or PDGFRA-associated mesenchymal tumors. However, the research of IncRNA AOC4P on GIST is not to be reported. In this study, we explored the effects of long non-coding RNA AOC4P on GIST to better understand the potential mechanism of GIST therapies.

**Materials and methods**

 Patients and specimens

Fresh GIST samples were obtained from 79 GIST patients between 2012 and 2016. The size of the GISTs ranged from 3 to 17 cm. The medians of the size in high-risk GISTs and low/medium-risk GISTs were 7.25 and 6.10 cm, respectively. All procedures in this study were performed under the regulation of ethical issues in hospital. All participants signed written informed consent form for this study. The study protocol was approved by the Institutional Review Board of China-Japan Union Hospital of Jilin University.

**Cells and siRNA transfection**

GIST-T1 (heterozygosis mutation type of KIT exon) and GIST-882 (homozygotic mutation type of KIT exon) cells were purchased from Cosmo Bio (Tokyo, Japan) and cultured in DMEM medium (Hyclone, USA) containing 10% fetal bovine serum and 1% penicillin streptomycin (Gibco, USA) at 37°C incubator (Forma, USA) containing 5% of CO2.

GIST-T1 and GIST-882 cells were inoculated into a six-well culture plate in a 5°C incubator overnight. The experiment had three groups to test the effect of AOC4P on GIST including negative control group (CN), silence AOC4P group (si AOC4P), and silence negative control group (si CT). Lipidosome2000 (Amersham Bioscience, Piscataway, NJ, USA) was used to transfect 1 μg si AOC4P and 1 μg si RNA cells as si AOC4P and si CT group, respectively. The sequences of si-AOC4P are as follows: sense: 5′-GUUAGGCGUCCUGGCAGAUU-3′ and antisense: 5′-CCUGGAGGUGAAACAAUU-3′.

**Quantitative real-time PCR (qRT-PCR) analysis of Inc AOC4P in tissues**

The total RNA of GISTs was extracted using TRIZol reagent (Thermo Fisher Scientific, Waltham, MA, USA). About 2 μg of total RNA was reverse transcribed by Superscriptor™ II according to the manufacturer’s protocol (Thermo Fisher Scientific). Real-time quantitative analysis was performed in the Real-Time Detection System (Thermo Fisher Scientific) by SYBR green I dye detection (Takara, Tokyo, Japan). The primers used in this study are as follows:

**Inc AOC4P forward, 5′-AAAGGAGGTGAGGGAATGTG-3′;**

**Inc AOC4P reverse, 5′-GCTGGGACTGGGAGATAC-3′;**

**U1 forward, 5′-ATACTTACCTGGCAGGGAG-3′;**

**U1 reverse, 5′-CAGGGGAAACGCGGAACGC-3′.**

The PCR amplifications were performed at 95°C for 3 minutes, followed by 35 cycles of thermal cycling at 95°C for 30 seconds, at 60°C for 15 seconds, and at 72°C for 15 seconds, terminated at 60°C for 15 seconds, and finally stored at 4°C. U1 was used as endogenous control to normalize the differences. Melt curves were performed to complete the whole cycles to ensure that nonspecific products were avoided. Roche LightCycler 480 qRT-PCR (Hoffman-La Roche Ltd., Basel, Switzerland) quantification
was performed by normalizing the cycle threshold (Ct) values with U1 Ct and analyzed with the 2^−ΔΔCt method.

Western blot analysis of the related EMT proteins in tissues
Total protein of GISTs was extracted by using the Tissue Total Protein Lysis buffer (Sangon Biotech Co., Ltd., Shanghai, China) according to the manufacturer’s protocol. Protein samples (40 µg) were separated on SDS–PAGE gel and transferred to polyvinylidene fluoride nitrocellulose blots. The blots blocked with 5% skim milk for 1 hour were incubated overnight at 4°C with rabbit polyclonal antibody TGF-β1 (1:1,000, orb7087; Biorbyt), rabbit polyclonal antibody ZEB1 (1:1,000, orb254960; Biorbyt, Cambridge, UK), rabbit polyclonal antibody E-cadherin (1:1,000, orb160843; Biorbyt), rabbit polyclonal antibody Vimentin (1:200, orb128909; Biorbyt), and rabbit polyclonal antibody Snail (1:1,000, orb95764; Biorbyt) and washed three times for 5 minutes with TBST (TBS, 1 mL/L Tween 20). Then, these blots were injected with HRP secondary antibodies goat anti rabbit IgG (1:10,000, orb108261; Biorbyt), incubated for 2 hours in dark, and then washed three times for 5 minutes with TBST, and the film was developed in the enhanced chemiluminescence (ECL) in dark room. The expression of protein samples was standardized according to β-actin (GE Healthcare, Piscataway, NJ, USA), then scanned and quantified by the ImageJ software.

Proliferative activity assay
The proliferative activity was measured by MTT method. The transfected cells were prepared for single-cell suspensions and adjusted to 1.0×10^4/mL. Then, the cell suspensions were inoculated into 96-well plates, in which each of the plates was injected with 100 µL cell suspensions. Then, the 96-well plates were incubated in a 37°C incubator containing 5% CO₂. The cell suspensions were incubated for 24, 48, 72, and 96 hours. The cell suspension was collected and then centrifuged at 20,000 rpm for 5–10 minutes. Then, 300 µL 1× binding buffer and 5 µL Annexin V-FITC (Beyotime Biotechnology Research Institute) were added and mixed at room temperature at dark incubation for 10 minutes. The cells were then centrifuged at 2,000 rpm for 5–10 minutes. Cells were washed in PBS and centrifuged at 2,000 rpm for 5–10 minutes. Then, 300 µL Annexin V-FITC binding buffer and 5 µL Annexin V-FITC (Beyotime Biotechnology Research Institute) were added and mixed at room temperature at dark incubation for 10 minutes. The remaining steps were the same as the tissue detection.

Statistical analysis
All the data were presented as mean ± standard deviation (SD). Data were analyzed with SPSS 19.0 software. Multiple comparisons were evaluated by repeated measures analysis of variance followed by the least significant difference-t test or Kruskal–Wallis test. P<0.05 was considered to be statistically significant.

Results
LncRNA AOC4P was highly expressed in GIST tissues
A total of 79 GIST patients were included with 39 low-risk cases, 14 medium-risk cases, and 26 high-risk cases. At the same time, 79 cases of paracancerous normal tissues were
taken. As shown in Figure 1, the expression of AOC4P in GIST tissues was higher than that in normal tissues ($P<0.05$). The expression of AOC4P in high risk GIST tissues was higher than that in low/medium-risk GIST tissues ($P<0.05$).

The expression of EMT-related proteins in GIST patients
As shown in Figure 2, the expression of TGF-β1, ZEB1, Vimentin, and Snail in normal tissues were lower than that in GIST tissues ($P<0.05$), and the expression of E-cadherin in normal tissues was higher than that in GIST tissues ($P<0.05$). Compared with high-risk GIST, the expression of TGF-β1, ZEB1, Vimentin, and Snail were significantly decreased in low/medium-risk GIST, while the expression of E-cadherin has significantly increased in low/medium-risk GIST.

Silence of AOC4P inhibited cell proliferation of GIST
As shown in Figure 3A, GIST cells in si AOC4P group were decreased by 60% compared to the si CT group ($P<0.05$).
Simultaneously, cell proliferation in si AOC4P group was significantly attenuated than in the CN group and si CT group, and si-AOC4P group showed a significant difference from si CT group at 72 and 96 hours ($P<0.05$, Figure 3B). In addition, the expression of si AOC4P in GIST-T1 cells were consistent with GIST882 cells, demonstrating that si AOC4P can inhibit cell proliferation of GIST.

Silence of AOC4P reduced cell migration ability
As shown in Figure 4, the migration ability in si AOC4P group was significantly decreased than in si CT group ($P<0.05$). There were no significant differences in si CT group and CN group.
Silence of AOC4P reduced cell invasive ability

The results in Figure 5A and B demonstrated that the invasive ability in si AOC4P group was significantly decreased than that in si CT group (P<0.05). Furthermore, the results in GIST-T1 cells were consistent with GIST882 cells, demonstrating that si AOC4P can reduce the invasive ability of GIST. There were no significant differences in cell invasive ability between si CT group and CN group.

Silence of AOC4P induced cell apoptosis

By Annexin V-FITC staining, it was found that si RNA AOC4P in si AOC4P group induced cell apoptosis compared with the si CT group (Figure 6A and B; P<0.05). Consistently, cell apoptosis rates of GIST-T1 and GIST-882 cells in si AOC4P group were 21.85% and 23.72%, respectively, revealing that cell apoptosis rate in si AOC4P group was higher than that in si CT group (P<0.05).

Effect of AOC4P for GIST on EMT

There was no significant difference in protein expression between si CT and CN groups. Simultaneously, the results of GIST-T1 and GIST-882 cells were consistent. As shown in Figure 7, the results of Western blot demonstrated that the expression of TGF-β1, Vimentin, ZEB1, and Snail in si AOC4P group were lower than that in si CT and CN groups (P<0.05), and E-cadherin in si AOC4P group has increased compared with si CT and CN groups (P<0.05).

Discussion

GIST is defined as a malignantly potential gastrointestinal tumor, causing impairments to patients. Therefore, the therapies...
Effect of lncRNA on GISTs

To cure GIST have received great attention. Based on investigations, it was illustrated that lncRNA showed potential values in clinical application. The predecessor pointed that lncRNA AOC4P has inhibited the migration of hepatoma carcinoma cell, indicating that AOC4P is an effective diagnosis for tumors. Therefore, in our investigation, we explored the association of AOC4P in GIST, and the results demonstrated that lncRNA AOC4P was highly expressed in GIST patients. Briefly, the expression of lncRNA AOC4P in GIST cells was increased than in normal cells. Our research is consistent with the previous research in 2017, indicating that AOC4P is essential for the survival and tumorigenicity of colorectal cancer cells by regulating protein degradation and ubiquitination.

It has been revealed that lncRNA participates in epigenetic regulation, thereby regulating the growth, apoptosis, infiltration, and transformation of tumor cells. To get an insight on the mechanism of AOC4P on GIST, we examined the cell proliferation, migration ability, invasive ability, and apoptosis activity, demonstrating that si AOC4P can inhibit cell proliferation, reduce migration and invasive ability, and promote cell apoptosis. Our data illustrated that silence of lncRNA AOC4P resulted in the decrease of cell proliferation, promoting apoptosis, and reduction of migration and invasive ability. Similar to the function of protein coding gene, lncRNAs can be divided into cancer-promoting lncRNA and cancer-suppressor lncRNA. Based on the investigation, we found that AOC4P was a cancer-promoting lncRNA. This will provide powerful evidence that AOC4P has striking effects on GIST patients.

Although investigations on the association of GIST and lncRNA are sporadic, GIST as an alimentary canal disease is similar to colorectal cancer. Therefore, lncRNA can be used as the marker of diagnosis or prognosis for GIST.
Furthermore, lncRNA AOC4P participates in tumor metastasis by inducing EMT. Therefore, our research illustrated the effect of lncRNA AOC4P for GIST on EMT. EMT is characterized as the process of oxophile epithelial cells converting to mesenchymal cells, inducing a series of changes including cell morphology, molecular features, and cell functions. EMT enhanced the ability of invasion and metastasis and promoted the growth of tumors. The TGF-β signaling pathway plays critical roles in multiple cancer biological processes, including growth, migration, invasion, differentiation, apoptosis, stemness, angiogenesis, and modification of the microenvironment, which can regulate EMT. Based on the features of EMT, we have explored the effects of si AOC4P on the related makers of EMT, demonstrating that GIST can influence the related factors of EMT.

In this research, we found that silence of AOC4P induced the increase of E-cadherin. It is well known that E-cadherin members develop the connection through immunoglobulin domains, connect with actin, and form the stable intercellular touch. Thus, reducing E-cadherin in GIST patients caused decrease of adhesive ability, chromosome elimination, and gene mutation, thereby exacerbating GIST. In addition, the decrease of cell adhesion molecule E-cadherin led to cytokeratin converting into vimentin which was similar to the mesenchymal cell. Vimentin, a major component of the cytoskeleton, is a well-known metastasis marker and a therapeutic target for overexpression in mesenchymal...
cells and reduces the ability of cells migration. In addition, vimentin, one of the markers of EMT, has the functions of cell signal transduction, adhesion, migration, and apoptosis. Our study revealed that the expression of vimentin in si AOC4P group was lower than that in si CT group, demonstrating that lncRNA AOC4P regulates EMT by affecting the production of vimentin. Snail is one of DNA binding proteins that recognizes and integrates with E-box, thereby inhibiting the expression of E-cadherin. In this research, silencing AOC4P could attenuate the expression of Snail in GIST cells, indicating that the expression of E-cadherin was enhanced and the proliferation of tumor was inhibited. Furthermore, Snail can induce loss of cell polarity, enhance cell move ability, and promote metastasis ability, and thus promote tumor invasion. Similar to Snail, ZEB, another important transcription factor, plays a striking effect on the occurrence and development of tumors and promotes tumorigenicity by regulating cell adhesion and microenvironment. It has been documented that Neddle4L regulated by ZEB-1 is a downstream of miR-23a pathway and has activated TGF-β pathway, thus exacerbating the tumors. Briefly, silence of AOC4P suppressed the migration of GIST by reducing the production of vimentin and Snail and enhancing the expression of E-cadherin.

Taken together, the administration of lncRNA AOC4P in GIST supports a role in the mechanism of cell proliferative ability, invasion ability, and apoptosis through EMT. At present, tumor size, cell proliferative ability, macroscopic vascular invasion, and cell apoptosis are considered as essential predictors of tumor recurrence. Our research suggested that GIST patients with high expression levels of AOC4P significantly affected EMT factors including vimentin, ZEB1, Snail, and E-cadherin. Our finding supported the concept that the expression level of AOC4P could serve as a prognostic biomarker for GIST.

**Conclusion**

lncRNA AOC4P silencing can reduce the proliferative ability, decrease the migration and invasion activity, and induce cell apoptosis. These findings added an insight into our
understanding of EMT in GIST. Along with further research, we identified that IncRNA AOC4P promoted GIST growth by inducing EMT for better understanding of the molecular mechanisms of IncRNA AOC4P. Most importantly, these studies suggested that IncRNA AOC4P may become a useful and potential prognostic biomarker, as well as an effective target for antimetastasis therapies for GIST. Moreover, the expression level of IncRNA AOC4P in GIST could be applied to predict the risk of disease recurrence and provide an effective idea of therapeutic target. However, no studies address the phenotype changes found in this study and the cells tend to become epithelial-like; therefore, the action of AOC4P lays more toward mesenchymal-to-epithelial transition, rather than EMT. These speculations should be tested in future experiments.

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