The miR-200 family: multiple effects on gliomas

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Abstract: Gliomas are the most common type of primary brain tumors. MicroRNAs (miRNAs) are small noncoding RNAs that can epigenetically regulate target gene expression. The microRNA 200 family includes miR-200a, 200b, 200c, 141 and 429. Numerous studies have indicated that members of the miR-200 family play an important role in glioma development and metastasis. In this review, we summarize the data from various studies and highlight the effects of miR-200 on glioma metastasis, therapeutic response and prognosis.

Keywords: glioma, miR-200 family, metastasis, chemoresistance, radioresistance

Introduction

Gliomas are the most common type of primary brain tumors, accounting for almost 30% of central nervous system tumors and 80% of all malignant brain tumors.\(^1,2\) Based on the World Health Organization (WHO) classification, gliomas can be divided into four grades – WHO I, II, III and IV.\(^3\) Glioblastoma (GBM; WHO grade IV) is the most common and aggressive primary brain tumor in adults, accounting for ~46% of primary malignant brain tumors.\(^4\) Gliomas are characterized by their rapid growth and high degree of infiltration. Despite the difficulty in surgically removing gliomas,\(^5\) the current primary treatments include surgical resection, radiotherapy and chemotherapy. Unfortunately, despite the remarkable development in surgery and adjuvant therapy, the median survival rate for patients with gliomas has not considerably improved over the past few decades. Furthermore, clinical outcomes remain poor due to the adverse events that accompany these treatments and the increasing resistance to radiotherapy and chemotherapy.\(^6-8\) The underlying mechanisms of glioma pathogenesis are still largely unknown. Thus, improving our understanding of glioma molecular pathogenesis is necessary to develop more efficacious and precise treatment schemes.

MicroRNAs (miRNAs) are small noncoding RNAs that are 17–24 nucleotides in length. miRNAs regulate target gene expression through inhibiting translation or degrading target mRNAs.\(^9\) It has been reported that miRNAs regulate cell growth associated with the development and metastasis of cancers.\(^10\) Some miRNAs have been specifically implicated in glioma pathogenesis. For example, recent reviews have indicated that circulating miRNAs could be potential glioma biomarkers and reported that miRNAs are associated with drug resistance, which may have direct therapeutic implications.\(^9,11,12\)

The miR-200 family consists of miR-200a, 200b, 200c, 141 and 429. All these miRNAs are derived from two different gene clusters. miR-200a, miR-200b and miR-429 are derived from chromosome 1p33.36, and miR-200c and miR-141 are derived from chromosome 1p35.36.
are derived from chromosome 12p13.3 (Table 1). These miRNAs are highly homologous, with only one nucleotide difference in their seed sequences (Table 1). Increasing evidence demonstrates that the microRNA-200 family is closely associated with glioma initiation, progression and metastasis. The goal of this review is to update the research field on the multiple roles of the miR-200 family in gliomas.

miR-200 expression in gliomas

Studies that have identified miRNAs that are aberrantly expressed in gliomas have provided important information regarding the roles of miRNAs in tumor biology. Studies that focused on the miRNA-200 family have offered new insight into glioma development and metastasis. Interestingly, while these studies have utilized different detection platforms and samples to identify differentially expressed miRNAs (Table 2), the majority found that miR-200a, 200b, 200c, 141 and 429 are downregulated in glioma tissues. More interestingly, miR-200a was consistently lower in grade IV (GBMs) gliomas compared to low-grade II and III (LGs) gliomas, suggesting that miR-200a is responsible for glioma histological grading. However, some members of the miR-200 family were upregulated in gliomas. For example, one study showed that miR-429 was upregulated in glioma compared to non-neoplastic brain tissues. Another study demonstrated that miR-141-3p was upregulated in high-grade gliomas (grades III and IV) compared to that of non-cancerous brain tissues or even LG gliomas (grades I and II). Intriguingly, although one study showed that miR-200b was upregulated in glioma compared to non-neoplastic brain tissues, inhibiting miR-200b expression enhanced pathological grading of glioma; therefore, miR-200b was still thought to be a tumor suppressor gene. Of note, the reduced expression of miRNAs in the miR-200 family in gliomas was associated with epigenetic regulation. One study reported that DNA methylation and histone modifications repressed miR-200a, 200b and 429 expression, which promoted glioblastoma progression.

The variation in miRNA expression data from these studies might reflect a context-dependent expression pattern that relies on histological type or glioma grade. Indeed, it was reported that dysregulation of miRNAs might be associated with tumor stage, grade and progression status. Therefore, the underlying mechanism of miRNA control of glioma warrants additional research.

miR-200 and metastasis of gliomas

Metastasis involves multiple steps that promote tumor cells to migrate from the primary tumor site and colonize in distant organs or tissues. Interestingly, extracranial metastasis is rare in malignant gliomas, which has been reported in only ~0.5% of patients. The low incidence of extracranial metastasis could be attributed to some intrinsic biological obstacles, such as lack of the lymphatic system, which is crucial for systemic dissemination, or the presence of dense dura around cerebral veins, which inhibits tumor cell migration.

One study indicated that miR-200a inhibits glioma cell growth, migration and invasion by targeting single-minded homolog 2-short form (SIM2-s). Similarly, many studies have demonstrated that miR-200b inhibits glioma cell proliferation and invasion. More specifically, miR-200b can target different genes, including cAMP responsive element-binding protein 1 (CREB1), zinc finger E-box binding homeobox 2 (ZEB2), prominin 1 (PROM1), extracellular signal-regulated kinase 5 (ERK5), CD133 and lactate dehydrogenase A (LDHA), which is associated with glioma cell proliferation and invasion. Therefore, targeting LDHA by miR-200b is regarded as a promising therapeutic strategy in glioma. Moreover, miR-200b was reported to be involved in blood-tumor barrier (BTB) permeability. For example, miR-200b overexpression was associated with reduced expression of RhoA and ROCKII and subsequently contributed to a decrease in BTB permeability. Therefore, downregulation of miR-200b may initiate a signaling cascade that increases BTB permeability and facilitates glioma cell invasion.

### Table 1

<table>
<thead>
<tr>
<th>miR-200 Family</th>
<th>Chromosome Location</th>
<th>Seed sequence of mature miRNAs</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>miR-200a</strong></td>
<td>chromosome 1p33.36</td>
<td>UAACACUGUCGUAAACGAUGU</td>
</tr>
<tr>
<td><strong>miR-200b</strong></td>
<td>chromosome 1p33.36</td>
<td>UAA U ACUCUGCUGUAAGUGA</td>
</tr>
<tr>
<td><strong>miR-200c</strong></td>
<td>chromosome 12p13.31</td>
<td>UAA U ACUGCGCGGUAAGUGA</td>
</tr>
<tr>
<td><strong>miR-141</strong></td>
<td>chromosome 12p13.31</td>
<td>UAA C ACUGCGCGUAAAGUGG</td>
</tr>
<tr>
<td><strong>miR-429</strong></td>
<td>chromosome 1p33.36</td>
<td>UAA U ACUGCGCGUAAAGCGU</td>
</tr>
</tbody>
</table>

**Note:** Seed nucleotide differences are highlighted.

**Abbreviation:** miRNAs, microRNAs.
On the other hand, several studies have reported that miR-200c plays an important role in regulating glioma cell growth and invasion. For example, one study showed that miR-200c overexpression impaired glioma cell proliferation and invasion by targeting moesin.35 Another study found that miR-200c prevented the invasion and migration of glioblastoma by activating EGFR pathways that reversed the epithelial–mesenchymal transition in glioblastoma.36 Intriguingly, due to the homology in seed sequences, miR-200c and miR-141 share the same target, ZEB1, which is known to inhibit glioma cell growth and migration.37 However, recent studies obtained inconsistent results. For example, one study reported that miR-141, acting as a tumor suppressor, inhibited glioma cell proliferation, migration and invasion by targeting TGF-β.25 While another study indicated that miR-141-3p promoted glioblastoma progression and temozolomide resistance by targeting p53.24 Similarly, another report suggested that miR-429 was a potential tumor-suppressive miRNA and inhibited glioblastoma proliferation by targeting SOX2,38 while a contrasting study reported that miR-429 was upregulated in glioma tissues compared to normal brain tissues. A decrease in miR-200b expression with increasing pathological grading of gliomas could become a useful independent prognostic factor for glioma.

### Table 2

<table>
<thead>
<tr>
<th>Study</th>
<th>Samples/controls</th>
<th>miR-200 expression</th>
<th>Conclusion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Su et al (2014)14</td>
<td>Samples: human glioma Controls: normal brain tissue</td>
<td>Decreased expression of miR-200a in glioma samples compared to normal brain tissue</td>
<td>miR-200a acted as a tumor suppressor by targeting the SIM2-s gene in gliomas</td>
</tr>
<tr>
<td>Berthois et al (2014)17</td>
<td>Samples: 24 primary GBMs Controls: 10 low grade brain tumors (LGs)</td>
<td>miR200a was downregulated in GBMs compared to LGs</td>
<td>miR200a was involved in glioma progression and therapeutic response</td>
</tr>
<tr>
<td>Liu et al (2014)18</td>
<td>Samples: 73 glioma tissues Controls: 30 normal brain tissues</td>
<td>miR-200b was downregulated in glioma tissues</td>
<td>miR-200b, as a tumor suppressor by targeting the RAB family, was a potential biomarker for glioma prognosis</td>
</tr>
<tr>
<td>Sun et al (2014)16</td>
<td>Samples: 88 cases of glioma specimens Controls: 25 normal brain tissues</td>
<td>miR-200b levels were decreased in primary glioma tissues compared to normal brain tissues</td>
<td>miR-200b had suppressive effects on glioma cells via targeting ZEB2</td>
</tr>
<tr>
<td>Wang et al (2015)23</td>
<td>Samples: primary gliomas from 123 patients (including 38 astrocytoma, 53 glioblastoma, and 32 ependymoma) Controls: normal brain tissues</td>
<td>miR-200b was increased in glioma tissues compared with normal brain tissues. A decrease in miR-200b expression with increasing pathological grading of gliomas</td>
<td>miR-200b levels were associated with the histological grading of gliomas. miR-200b could become a useful independent prognostic factor for glioma</td>
</tr>
<tr>
<td>Qin et al (2017)15</td>
<td>Samples: human glioma samples (including grade II, grade III, and grade IV glioma tissues) Controls: paratumor tissues</td>
<td>miR-200c was reduced in glioma tissues compared to paratumor tissues</td>
<td>miR-200c played an important role in regulating glioma by targeting moesin</td>
</tr>
<tr>
<td>Peng et al (2016)20</td>
<td>Samples: glioma tissues from 36 patients with primary glioma Controls: adjacent normal tissues</td>
<td>miR-141 was lower in glioma compared to adjacent non-cancerous tissues</td>
<td>miR-141 acted as a tumor suppressor by targeting TGF-β2</td>
</tr>
<tr>
<td>Zhou et al (2017)24</td>
<td>Samples: 27 human glioma specimens Controls: 5 normal brain tissues</td>
<td>miR-141-3p was increased in glioma tissues</td>
<td>miR-141-3p promoted tumor growth by targeting p53 and increased resistance in glioma cells to temozolomide</td>
</tr>
<tr>
<td>Chen et al (2015)21</td>
<td>Samples: 12 glioma tissues Controls: adjacent non-tumor tissues</td>
<td>miR-429 was lower in glioma tissues than in adjacent non-neoplastic tissues</td>
<td>miR-429 had an important function in glioma invasion through BMK1 suppression</td>
</tr>
<tr>
<td>Sun et al (2016)22</td>
<td>Samples: 92 gliomas (including 11 grade I, 37 grade II, 24 grade III, and 20 grade IV) Controls: non-neoplastic brain tissues</td>
<td>miR-429 was increased in glioma tissues compared to non-neoplastic brain tissues</td>
<td>miR-429 was upregulated in glioma tissues. Patients with high miR-429 level had lower 5-year survival rates</td>
</tr>
</tbody>
</table>

Abbreviations: miRNA, microRNA; GBMs, glioblastomas.
that the miR-200 family could modulate the tumor immune response. For example, myeloid-derived suppressor cells (MDSCs) can produce reactive oxygen species and suppress tumor immune response and modulate the tumor environment. Additionally, it was reported that miR-200c plays a significant role in the regulation of tumor-associated MDSCs. However, the exact relationship between the miR-200 family and glioma immunotherapy is still largely unknown. Therefore, future detailed studies are needed to improve the efficacy of immunotherapy.

Overall, the current data suggest that the miR-200 family could influence clinical outcomes and glioma prognosis through multiple mechanisms. Indeed, it has been clearly demonstrated that higher miR-200b expression correlates with better outcomes and a significantly higher 5-year survival rate in glioma patients and that reduced miR-200b expression might be associated with poor prognosis.

In contrast, one study reported that high miR-429 expression correlates with poor prognosis in glioma patients, while other studies indicated that miR-429 functions as either an oncogene or a tumor suppressor. The underlying mechanism for this discrepancy is unknown; therefore, more research is needed to clarify the roles of miR-429 in gliomas.

**Interactions among different members of the miR-200 family in gliomas**

It is well known that, similar to other miRNA families, each miRNA in the miR-200 family can regulate the expression of several mRNAs, and each mRNA can also be regulated by several miRNAs, forming a complex regulatory network (Table 3). Importantly, in gliomas, the target genes dysregulated by miR-200 are associated with many conserved signaling pathways involved in cell processes such as cell proliferation, apoptosis, invasion and drug resistance. Because miR-200 can target multiple downstream genes in glioma tissues, miR-200 might play both oncogenic and anticancerous roles. For instance, TGF-β2 regulates many cellular processes including proliferation, differentiation, adhesion and migration. TGF-β2 expression is upregulated in glioma, and TGF-β2 has been found to play an important role in glioma initiation and development. In this context, miR-141 acts as a tumor suppressor by targeting TGF-β2. However, the tumor suppressor p53 is also a direct target of miR-141. Therefore, miR-141 may also function as an oncogenic factor through negatively targeting p53 to promote tumor growth and inhibit cell apoptosis. Future research should focus on the specific biological context of miR-200 in gliomas.
Table 3 Target genes of the miR-200 family in glioma tissues

<table>
<thead>
<tr>
<th>miRNA</th>
<th>miRNA targets (mRNA)</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>miR-200a</td>
<td>SIM2-s, TGF-β2</td>
<td>16,40</td>
</tr>
<tr>
<td>miR-200b</td>
<td>RAB family, ZEB2, CREB1, CD133, LDHA, RhoA, ROCK2, PROM1, ERK5</td>
<td>10,18,19,31–35</td>
</tr>
<tr>
<td>miR-200c</td>
<td>Moesin, VEGF, HIF-1α, MMP2, ZEB1</td>
<td>15,36,37</td>
</tr>
<tr>
<td>miR-141</td>
<td>ATF5, ZEB1, TGF-β2, p53, HOTAIR, SKA2</td>
<td>14,20,24,37,42</td>
</tr>
<tr>
<td>miR-429</td>
<td>BMK1, SOX2</td>
<td>21,38</td>
</tr>
</tbody>
</table>

Abbreviation: miRNA, microRNA.

Conclusion
Numerous studies have shown that members of the miR-200 family, as epigenetic regulatory molecules, can regulate physiological and pathological processes through targeting multiple downstream genes, consequently affecting proliferation and invasion of glioma cells as well as the therapeutic response and prognosis of gliomas. Intriguingly, the contradictory roles of microRNAs, especially miR-141 and miR-429, may differentially impact glioma development and progression. In the future, more detailed studies are needed to delineate the underlying mechanisms by which miRNAs in the miR-200 family affect glioma cells to develop more efficient treatments.

Disclosure
The authors report no conflicts of interest in this work.

References