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Abstract

Despite of the recent advances in diagnostic and therapeutic approaches, cancer remains as the leading cause of death worldly with diverse causal factors regarding genes and environment. Invasion and metastasis, as one of the most important hallmarks for cancer, have restrained the successful clinical therapy and are the primary causes of death among cancer patients. So far, most chemotherapeutic drugs are not effective for metastatic cancer due to drug resistance and serious side effects. Therefore, it is urgently essential to develop more effective therapeutic methods. Owing to their diverse biological activities and low toxicity, naturally active compounds derived from Chinese medicines, as a complementary and alternative approach, are reported to promote the therapeutic index and provoked as an excellent source for candidates of anti-metastatic drugs. With the rapid development of molecular biology techniques, the molecular mechanisms of the effects of potential anti-invasive and metastatic Chinese medicines are gradually elucidated. This chapter reviews the potential anti-invasive and metastatic mechanisms of naturally active compounds from Chinese medicines, including suppression of EMT, proteases and cancer-induced angiogenesis, anoikis regulation of circulating tumor cells and regulation of miRNA-mediated gene expression, providing scientific evidence for clinically using Chinese medicines in the field of cancer therapy.

Keywords: Chinese medicines, anti-invasion and metastasis, molecular mechanisms, cancer therapy
1. Introduction

Despite all the recent advances in diagnostic and therapeutic approaches, cancer remains the leading cause of death and primary public health hazard all over the world [1, 2]. With diverse causal factors (genetic and environmental, physical, psychological and biochemical factors), cancer has a various disease spectrum to more than a hundred different kinds of malignancies, such as lung cancer, breast cancer, renal carcinoma, hepatocellular carcinoma, and so on [3]. It is a progressive disease with multiple pathological processes covering cancer initiation, development, and metastasis. Cancer is characterized by several key hallmarks [4-6], namely uncontrolled replication ability of abnormal cells, resistance to programmed cell death, invasion into the surrounding extracellular matrix (ECM), sustained capability of angiogenesis, and metastatic spread to other sites.

As one of the most important hallmarks for cancer, metastasis is an intricate process concerning the following six steps (as shown in Figure 1): (i) detachment of cancer cells through degrading ECM, (ii) local migration and invasion into the surrounding tissues, (iii) intravasation into blood and/or lymphatic vessel systems, (iv) survival and circulation in the circulatory system, (v) extravasation into the targeted secondary organ site, and (vi) multiplication and formation of a secondary tumor [7-9]. During these steps, the metastatic cancer cells should have special properties to overcome the obstacles, such as the capability of invasion, resistance to anoikis, and angiogenesis. Basically, these steps are regulated by multiple factors, including but not limited to changes of expression of related genes, cytoskeleton remodeling, proteolysis degradation of ECM, and so on [10]. Metastasis is a nonrandom process, and different metastatic cancer types possess their corresponding preferred sites of metastasis. For instance, the preferred sites of breast cancer cells are lung, liver, and bone [11]. Since invasion and metastasis restrain the successful clinical therapy and are the primary causes of death among cancer patients, it has been widely accepted that invasion and metastasis become a highlighted topic of research interests, and active efforts are still needed to understand the underlying molecular mechanisms and develop effective anti-metastatic therapies.

At the present day, there are three conventional therapeutic approaches which are used to treat metastatic cancers, namely surgical resection, chemotherapy, and radiotherapy. Though remain as the main treatment approach for metastatic cancer patients, most chemotherapeutic drugs are not effective for metastatic cancer due to drug resistance and serious side effects. Most chemotherapeutic drugs fail to selectively kill cancer cells without destroying normal cells at the sites of metastasis [12] and thus cause severe toxicity, such as appetite loss, weight loss, insomnia, fatigue, even life threat etc [13, 14]. Although chemotherapeutics significantly leads to regression of the primary tumor, some investigations even report that it may also promote and enhance metastatic formation of a secondary tumor [15, 16]. Besides, metastatic cancers are demonstrated to be largely resistant against chemotherapeutics. Despite that various approaches have been applied to treat metastatic cancers, the clinical outcomes of metastatic cancer treatment are still not at a satisfactory level. Therefore, it is urgently essential to develop more effective therapeutic methods with minimal adverse effects for metastatic cancer treatment.
Traditional medicine, such as Chinese medicine, has been shown to exhibit various pharmacological activities and used in treatment of various diseases in Asian countries and regions for a long time [17]. The numerous natural compounds obtained from Chinese medicines chemically range from flavonoids and polyphenols to mineral salts, which have been reported to be an excellent source for anti-cancer agents [18]. Owing to their long-lasting efficacy, diversity in biological activities, and low toxicity, natural active products from Chinese medicines, including single compounds and various extracts, are being developed for treatment of metastatic cancer [19, 20]. In line with such a concept, several natural active products from Chinese medicines have been currently investigated as a complementary and alternative approach, and their anti-metastatic properties have been focused to find newly discovered mechanisms with the hope to promote the therapeutic index of metastatic cancer.

With the rapid development of molecular biology techniques, the molecular mechanisms underlying the effects of potential anti-invasive and metastatic Chinese medicines are gradually elucidated. Understanding of the underlying molecular mechanisms may in turn lead to the discovery of novel anticancer drugs. In summary, this chapter reviews the anti-invasive and metastatic effect of natural active compounds from Chinese medicines and their molecular mechanisms. Tables 1 and 2 respectively summarized the potential underlying molecular mechanisms of single pure compounds and various extracts from Chinese medicines to suppress cancer invasion and metastasis.

Figure 1. The process involving in cancer metastasis.

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<table>
<thead>
<tr>
<th>Single pure compound</th>
<th>Cancer type</th>
<th>Study type</th>
<th>Mechanism of actions</th>
<th>Ref. (PMID)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arctigenin</td>
<td>Breast cancer</td>
<td>In vitro MCF-7 and MDA-MB-231 cells</td>
<td>Suppress MMP-9 and uPA</td>
<td>28035371</td>
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<tr>
<td></td>
<td>Colorectal cancer</td>
<td>In vitro CT26, MC38, Caco-18Co and SW620 cells and in vivo BALB/c female mice</td>
<td>Induce anoikis via MAPKs signaling, inhibit EMT through increasing E-cadherin and decreasing N-cadherin, vimentin, β-catenin, and Snail and downregulate MMP-2/9</td>
<td>27618887</td>
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<tr>
<td>Astragaloside IV</td>
<td>Breast cancer</td>
<td>In vitro MDA-MB-231 cells and in vivo athymic Balb/c nude mice</td>
<td>Downregulate Vav3 and MMP-2/9</td>
<td>27930970</td>
</tr>
<tr>
<td>Berberine</td>
<td>Hepatocellular carcinoma</td>
<td>In vitro MHCC-97L, Bel-7402, SMMC-7721 cells and in vivo nude mice</td>
<td>Downregulate uPA and suppress Id-1 via HIF-1a/VEGF pathway</td>
<td>27092498, 25496992</td>
</tr>
<tr>
<td></td>
<td>Nasopharyngeal carcinoma</td>
<td>In vitro HONE1 cells</td>
<td>Suppress Rho GTPases including RhoA, Cdc42, and Rac1</td>
<td>19513345</td>
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<tr>
<td>Notoginsenoside R1</td>
<td>Colorectal cancer</td>
<td>In vitro HCT-116 cells</td>
<td>Reduce MMP-9, integrin-1, E-selectin and ICAM-1 expressions</td>
<td>27840961</td>
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<tr>
<td>Matrine</td>
<td>Prostate cancer</td>
<td>In vitro DU145 and PC-3 and male Balb/c nude mice inoculated subcutaneously with cells</td>
<td>Downregulate MMP-2/9</td>
<td>28000853</td>
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<tr>
<td>Bibenzyl</td>
<td>Lung cancer</td>
<td>In vitro H292 cells</td>
<td>Suppress EMT markers (vimentin and Snail) and increase the level of E-cadherin and induce anoikis by reduction of activated protein kinase B (p-AKT) and activated extracellular signal-regulated kinase (p-ERK)</td>
<td>24692728</td>
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<tr>
<td>Curcumin</td>
<td>Lung cancer</td>
<td>In vitro H460 cells</td>
<td>Sensitize anoikis by down-regulating Bcl-2</td>
<td>20127174</td>
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<tr>
<td>Imperatorin</td>
<td>Lung cancer</td>
<td>In vitro H23, H292 and A549 cells</td>
<td>Sensitize anoikis by down-regulating Mcl-1 protein and up-regulating Bax</td>
<td>23108812</td>
</tr>
<tr>
<td>Artonin E</td>
<td>Lung cancer</td>
<td>In vitro H460, A549 and H292 cells</td>
<td>Sensitize anoikis by down-regulating Mcl-1 protein</td>
<td>23225436</td>
</tr>
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<td>Single pure compound</td>
<td>Cancer type</td>
<td>Study type</td>
<td>Mechanism of actions</td>
<td>Ref. (PMID)</td>
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<tr>
<td>Ecteinascidin 770</td>
<td>Lung cancer</td>
<td>In vitro H23 and H460 cells</td>
<td>Sensitize anoikis by down-regulating McI-1 protein and up-regulating Bax</td>
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<tr>
<td>Renieramycin M</td>
<td>Lung cancer</td>
<td>In vitro H460 cells</td>
<td>Sensitize anoikis by down-regulating survival proteins p-ERK and p-AKT and anti-apoptotic proteins BCL2 and MCL1</td>
<td>27069144</td>
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<tr>
<td>Oroxylin A</td>
<td>Lung cancer</td>
<td>In vitro A549 cells and in vivo nude mice</td>
<td>Sensitize anoikis by inactivating the c-Src/AKT/HK II pathway</td>
<td>23500080</td>
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<tr>
<td>Geraniin</td>
<td>Lung cancer</td>
<td>In vitro A549 cells</td>
<td>Inhibit the TGF-β1-induced EMT</td>
<td>26169124</td>
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<td>Genipin</td>
<td>Hepatocellular carcinoma</td>
<td>In vitro HepG2 and MHCC97L cells and in vivo male nude mice</td>
<td>Overexpress TIMP-1 and inhibit MMP-2</td>
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<td>Kukoamine A</td>
<td>Glioblastoma</td>
<td>In vitro C6, U251 and WJ1 cells and in vivo nude mice (BALB/C-nu/nu)</td>
<td>Inhibit EMT and induce anoikis by downregulating expressions of C/EBPβ and 5-LOX</td>
<td>27824118</td>
</tr>
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<td>Gigantol</td>
<td>Lung cancer</td>
<td>In vitro H460 cells</td>
<td>Decrease EMT markers including N-cadherin, vimentin, and Slug</td>
<td>26733180</td>
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<tr>
<td>Moscatilin</td>
<td>Lung cancer</td>
<td>In vitro H460 cells</td>
<td>Inhibit EMT by suppressing mesenchymal cell markers (vimentin, Slug, and Snail) and induce anoikis by survival proteins (ERK and Akt) suppression and Cav-1 down-regulation</td>
<td>26384689</td>
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<tr>
<td>2,3,5-Trimethoxy-4-cresol</td>
<td>Lung cancer</td>
<td>In vitro A549 cells</td>
<td>Suppress Akt, MMP-2 and MMP-9 and increase E-cadherin and TIMP-1</td>
<td>25951809</td>
</tr>
<tr>
<td>Deoxyelephantopin</td>
<td>Lung cancer</td>
<td>In vitro A549 cells</td>
<td>Suppress MMP-2, MMP-9, uPA, and uPAR</td>
<td>25686703</td>
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<td>Bufalin</td>
<td>Lung cancer</td>
<td>In vitro NCI-H460 cells</td>
<td>Suppress MMP-2, MAPKs, and NF-κB</td>
<td>26446205</td>
</tr>
<tr>
<td>Epicatechin-3-gallate</td>
<td>Lung cancer</td>
<td>In vitro A549 cells and in vivo BALB/c nude mice</td>
<td>Inhibit the TGF-β1-induced EMT by up-regulating epithelial marker (E-cadherin) and down-regulating mesenchymal markers (fibronectin and p-FAK)</td>
<td>27224248</td>
</tr>
<tr>
<td>Single pure compound</td>
<td>Cancer type</td>
<td>Study type</td>
<td>Mechanism of actions</td>
<td>Ref. (PMID)</td>
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<tr>
<td>Rocaglamide-A</td>
<td>Prostate cancer, cervical cancer</td>
<td>In vitro PC-3, MDA- MB-231, HCT116, HeLa, and 293T cells</td>
<td>Inhibit the activity of Rho GTPases RhoA, Rac1 and Cdc42</td>
<td>27340868</td>
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<tr>
<td>Chamaejasmin B</td>
<td>Breast cancer</td>
<td>In vitro MDA-MB-231, ZR75-1 and 4T1 cells and in vivo BALB/c mice</td>
<td>Block TGF-beta induced EMT</td>
<td>27374079</td>
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<tr>
<td>Artesunate</td>
<td>Cervical cancer</td>
<td>In vitro CaSkii and Hela cells</td>
<td>Inhibit HOTAIR and COX-2 expressions</td>
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<tr>
<td>Ginsenoside Rd</td>
<td>Breast cancer</td>
<td>In vitro 4T1 cells and in vivo BALB/c mice</td>
<td>Derepress miR-18a-mediated Smad2 expression</td>
<td>27641158</td>
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<tr>
<td>Quercetin</td>
<td>Colorectal cancer</td>
<td>In vitro CT26 and MC38 cells and in vivo BALB/c female mice</td>
<td>Induce apoptosis through the MAPKs pathway, regulate EMT markers including E-, N-cadherin, β-catenin, and snail and regulate MMPs and TIMPs</td>
<td>27823633</td>
</tr>
<tr>
<td>Sulforaphane</td>
<td>Lung cancer</td>
<td>In vitro H1299, 95C and 95D cells and in vivo male BALB/c nude mice</td>
<td>Inhibit EMT by silencing miR-616-5p</td>
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<tr>
<td>Tricetin</td>
<td>Osteosarcoma</td>
<td>In vitro U2OS and HOS cells</td>
<td>Repress MMP-9 via p38 and Akt pathways</td>
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<tr>
<td>Arsenic trioxide</td>
<td>Chondrosarcoma</td>
<td>In vitro HCS-2/8, OUMS-27, SW1353, and JJ012 cells</td>
<td>Inhibit EMT via the miR-125b/Stat3 axis</td>
<td>27576314</td>
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<td>Cucurbitacin B</td>
<td>Breast cancer</td>
<td>In vitro MDA-MB-231 and 4T1 cells</td>
<td>Inhibit angiogenesis via downregulating VEGF/FAK/MMP-9 signaling</td>
<td>27210504</td>
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<tr>
<td>2,3,5,4′-Tetrahydroxystilbene-2-O-D-glucoside</td>
<td>Colorectal cancer</td>
<td>In vitro HT-29 cells</td>
<td>Suppress MMP-2 and ICM-1 via NF-κB pathway</td>
<td>27278028</td>
</tr>
<tr>
<td>7,7″-Dimethoxyagastisflavone</td>
<td>Melanoma</td>
<td>In vitro B16F10 cells and in vivo female C57BL/6J/Narl mice</td>
<td>Down-regulate the polymerization of F-actin via Cdc42/Rac1 pathway and inhibit lamellipodia formation via suppressing CREB phosphorylation</td>
<td>27487150</td>
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<tr>
<td>Nobiletin</td>
<td>Osteosarcoma</td>
<td>In vitro U2OS and HOS cells</td>
<td>Block ERK and JNK-mediated MMPs expression</td>
<td>27144433</td>
</tr>
</tbody>
</table>

Table 1. Summary on the potential underlying molecular mechanisms of single pure compound from Chinese medicines to suppress cancer invasion and metastasis.
2. Suppression of epithelial-mesenchymal transition

Recent studies clearly showed that epithelial-mesenchymal transition (EMT) plays an important role in the metastasis of cancers [21]. As the fundamental step during cancer metastasis, EMT is a complex process during which immotile epithelial cells undergo a morphological transformation into motile mesenchymal-appeared cells, triggering cancer cells to detach from the primary site via the loss of cell-to-cell junctions and thus promoting cell migration [22]. There are

### Table 2. Summary on the potential underlying molecular mechanisms of various extracts from Chinese medicines to suppress cancer invasion and metastasis.

<table>
<thead>
<tr>
<th>Various extracts</th>
<th>Cancer type</th>
<th>Study type</th>
<th>Mechanism of actions</th>
<th>Ref. (PMID)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ethanol extract of baked Gardeniae Fructus</td>
<td>Melanoma</td>
<td>In vitro B16F10 and in vivo C57BL/6 mice</td>
<td>Inhibiting the release of pro-angiogenic factors from tumor cells</td>
<td>27779658</td>
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<tr>
<td>Mixture of flavonoids extracted from Korean Citrus aurantium</td>
<td>Lung cancer</td>
<td>In vitro A549 cells and in vivo NOD/SCID mice</td>
<td>Induce apoptosis through regulating the apoptosis related protein cleaved caspase-3 and p-p53</td>
<td>No</td>
</tr>
<tr>
<td>Bibenzyl compounds isolated from Dendrobium pulchellum</td>
<td>Lung cancer</td>
<td>In vitro</td>
<td>Induce anoikis</td>
<td>23472473</td>
</tr>
<tr>
<td>Aqueous extract of Andrographis paniculata</td>
<td>Esophageal cancer</td>
<td>In vitro EC-109 and KYSE-520 cells</td>
<td>Inhibit anoikis resistance</td>
<td>26885447</td>
</tr>
<tr>
<td>Methanol extracts of Euphorbia humifusa Willd</td>
<td>Breast cancer</td>
<td>In vitro MDA-MB-231 and in vivo Balb/c mice</td>
<td>Reduce TNFα-induced MMP-9 expression</td>
<td>27776550</td>
</tr>
<tr>
<td>Ethanol extract of Lophatheri Herba</td>
<td>Fibrosarcoma, breast cancer, prostate carcinoma and melanoma</td>
<td>In vitro HT1080, MDA-MB231, DU145, B16F10 cells and in vivo C57BL/6j mice and ICR mice</td>
<td>Suppress tumor-induced angiogenesis by decreasing the pro-angiogenic factors</td>
<td>27808120</td>
</tr>
<tr>
<td>Coptidis Rhizoma aqueous extract</td>
<td>Hepatocellular carcinoma</td>
<td>In vitro Hep G2 and MHCC97-L cells and in vivo nude mice</td>
<td>Suppress Rho/ROCK signaling pathway and inhibit VEGF secretion</td>
<td>21106616 24363282</td>
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<tr>
<td>Methanol extracts and butanol extracts of Oldenlandia diffusa</td>
<td>Breast cancer</td>
<td>In vitro MCF-7 cells</td>
<td>Inhibit PMA-induced MMP-9 and ICAM-1 expressions</td>
<td>27876502</td>
</tr>
<tr>
<td>Annona muricata leaf aqueous extract</td>
<td>Breast cancer</td>
<td>In vitro 4 T1 cells and in vivo female BALB/c mice</td>
<td>Induce the apoptosis</td>
<td>27558166</td>
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<tr>
<td>Ethanol extract of Siegesbeckia orientalis</td>
<td>Endometrial Cancer</td>
<td>In vitro RL39-5 and HEC-1A</td>
<td>Reverse the TGFβ1-induced EMT</td>
<td>27527140</td>
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<tr>
<td>Polyphenols of Artemisia annua L.</td>
<td>Breast cancer</td>
<td>In vitro MDA-MB-231 cells</td>
<td>Suppress EMT by inhibiting MMP-2/-9 and vascular cell adhesion molecule-1</td>
<td>27151203</td>
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<tr>
<td>Gegen Qinlian decoction</td>
<td>Renal carcinoma</td>
<td>In vitro ACHN and Caki-1 cells and in vivo male BALB/c nude mice</td>
<td>Suppress neoangiogenesis via MMP-2 inhibition</td>
<td>25228536</td>
</tr>
</tbody>
</table>

Table 2. Summary on the potential underlying molecular mechanisms of various extracts from Chinese medicines to suppress cancer invasion and metastasis.
three different subtypes of EMT, and the third subtype of EMT is associated with the invasion and metastasis of cancers [23]. EMT-phenotypic cells can decrease the level of epithelial marker E-cadherin, a junction protein for cell-cell contact. Besides, they can also increase the level of mesenchymal markers, such as N-cadherin, β-catenin, and vimentin, as well as promote transcription factors of EMT switch, such as Slug and Snail [24, 25]. As EMT has been significantly linked to the metastatic behaviors of cancer cells, natural products obtained from Chinese medicines with the ability to suppress EMT are attracting attention for the development of anti-metastasis therapies.

Among potential natural products, geraniin, a polyphenolic component derived from Phyllanthus amarus, has gained considerable attention over the past decade. Previous study has demonstrated that EMT can be induced by transforming growth factor-beta 1 (TGF-β1) and thus stimulates the migration and invasion of lung adenocarcinoma. Geraniin has been shown to inhibit TGF-β1-induced EMT of lung cancer A549 cells in vitro by inducing the epithelial marker E-cadherin and suppressing Snail and vimentin [26]. A compound derived from Dendrobium ellipsoidium, bibenzyl 4,5,4′-tri hydroxy-3,3′-dimethoxybibenzyl was shown to inhibit EMT of lung cancer cells via down-regulating EMT markers (vimentin and Snail) and upregulating E-cadherin [27]. Such EMT suppression was also observed in lung cancer cells treated with other single compounds obtained from Chinese medicine, such as moscatilin [28], gigantol [29], and epicatechin-3-gallate [30]. A flavonoid obtained from Stellera chamaejasme L., namely chamaejasmenin B, was also reported to block the TGF-β-induced EMT in breast cancer [31]. 5-lipoxygenase (5-LOX) is an enzyme to convert arachidonic acid to leukotrienes [32] and abrogating its expression can inhibit the migration, invasion, and metastasis of cancer cells by suppressing EMT via inactivating E-cadherin and activating snail [33]. CCAAT/enhancer binding protein β (C/EBPβ) was also reported to be related to the migration, invasion, and metastasis of cancer cells by EMT regulation [34]. Kukoamine A, a spermine alkaloid extracted from Cortex lycii radicis, was demonstrated to suppress the migratory and invasive ability of human glioblastoma cell both in vitro and in vivo, and this action was mediated through EMT attenuation via decreasing the levels of 5-LOX and C/EBPβ [35]. Likewise, similar EMT inhibitory effects have also been observed in various extracts from Chinese medicines. Siegesbeckia orientalis Linne is a traditionally used Chinese medicinal herb that exhibits various pharmacological activities. Its ethanol extract (SOE) has been reported as a potential anti-metastatic agent by reversing the TGFβ1-induced EMT via ERK1/2, JNK1/2, and Akt pathways [36]. SOE can inhibit the migration and invasion of endometrial cancer RL95-2 and HEC-1A cells in a dose-dependent manner. Artemisia annua L. is a traditional medicine which has been applied for treating multiple diseases. The polyphenolic compounds from Artemisia annua L. (pKAL) were found to exhibit anti-metastatic property on highly metastatic breast cancer cells MDA-MB-231 [37]. This anti-metastatic property of pKAL was achieved through suppressing EMT by inhibiting MMP-2/-9 and vascular cell adhesion molecule-1 (VCAM-1).

3. Suppression of proteases expression

Matrix metalloproteinases (MMPs) is regarded as primary factors to trigger metastasis [38]. As extracellular zinc-dependent endopeptidases, they can degrade the basement membrane
and ECM and thus play an important role in the migration and invasion of cancers. There are 23 members in MMPs family, among which MMP-2 and MMP-9 are considered to be the key enzymes and play crucial roles in cancer metastasis [39, 40]. The activities of MMPs are finely mediated by tissue inhibitors of metalloproteinases (TIMPs) via their non-covalent binding to the active zinc-binding sites of MMPs [41]. In addition, as a serine-specific protease, urokinase-type plasminogen activator (uPA) can also degrade ECM via binding to uPA receptor (uPAR) and activating plasmin [42]. It is well-known that reorganization of the actin cytoskeleton plays an important role in the migration of cancer cell [43]. This process is mainly regulated by the Rho family GTPases, such as RhoA, Rac1, and Cdc42 via a shuttle between an inactive GDP-bound form and an active GTP-bound form [44, 45]. Since these proteases play an important role in cancer invasion and metastasis via proteolysis, natural products obtained from Chinese medicines with the ability to suppress these proteases are attracting attention for the development of anti-metastasis therapies.

As a phytoestrogen-botanical lignan derived from Arctium lappa, arctigenin was shown to exert its anti-metastatic property through suppressing MMP-9 and uPA of breast cancer cells via inhibiting the upstream signaling pathways including Akt, NF-κB, and MAPK (ERK 1/2 and JNK 1/2), which is dependent to the modulation on estrogen receptor (ER) expression [46]. Such protease regulation was also observed in breast cancer cells treated with astragaloside IV [47]. Notoginsenoside R1 (NGR1) is a primary compound in Panax notoginseng, and its anti-metastatic property has also been revealed [48]. NGR1 can inhibit the migration, invasion, and adhesion of cultured human colorectal cancer cells (HCT-116) via suppressing MMP-9, integrin-1, E-selectin, and ICAM-1 expressions. Such inhibition on colorectal cancer cells was also observed when treated with 2,3,5,4′-tetrahydroxystilbene-2-O-β-D-glucoside [49]. As an alkaloid derived from Sophora flavescens, matrine can inhibit the invasion and migration of castration-resistant prostate cancer DU145 and PC3 cells by suppressing MMP-9 and MMP-2 expressions through NF-κB pathway [50]. The phenol derived from Taiwanese edible fungus Antrodia cinnamomea, 2,3,5-trimethoxy-4-cresol, was recently described as an effective anti-metastatic agent against lung cancer via suppressing Akt, MMP-2 and MMP-9, and increasing E-cadherin and TIMP-1 [51]. Such protease regulation was also observed in lung cancer cells treated with other single compounds derived from Chinese medicine, such as deoxyelephantopin [52] and bufalin [53]. Genipin, a natural compound obtained from the fruit of Gardenia jasminoides, was reported to exhibit anti-metastatic effect on hepatocellular carcinoma both in cell and animal model. This effect may be related with TIMP-1 overexpression and MMP-2 inhibition of genipin [54]. As an isoquinoline alkaloid isolated from Coptidis rhizome and other medicinal plants, berberine has been shown to exhibit multiple pharmacological actions in treating human diseases, including cancers [55]. Recently, it was reported to inhibit nasopharyngeal carcinoma cell migration and invasion in vitro through suppressing Rho GTPases including RhoA, Rac1, and Cdc42 [56]. The anti-metastatic ability of Rocaglamide-A was also recently described via inhibiting the activity of Rho GTPases RhoA, Rac1, and Cdc42 [57]. As a dietary flavonoid in Eucalyptus honey and Myrtaceae pollen, tricetin was shown to attenuate osteosarcoma cell migration via suppressing MMP-9 via p38 and Akt pathways [58]. Such inhibition on osteosarcoma cells was also observed when treated with nobiletin [59]. The compound obtained from Taxus x media cv. Hicksii, 7,7″-Dimethoxyagastisflavone (DMGF) has been reported to inhibit the invasion and metastasis of melanoma cells in vivo and in vitro.
The mechanism study provided evidence that DMGF can downregulate the polymerization of F-actin via Cdc42/Rac1 pathway and inhibit lamellipodia formation via suppressing cAMP response element-binding protein (CREB) phosphorylation. Likewise, similar protease inhibitory effects have also been observed in various extracts from Chinese medicines. The methanol extracts of *Euphorbia humifusa* Willd was reported to have anti-metastatic effects on breast cancer both in vitro and in vivo via reducing TNFα-induced MMP-9 expression [61]. In addition, the methanol extracts and butanol extracts of *Oldenlandia diffusa* were also shown to block the metastasis of breast cancer via inhibiting PMA-induced MMP-9 and ICAM-1 expressions [62].

4. Suppression of cancer-induced angiogenesis

Angiogenesis is a normal physiological process to sprout new vessels during the development of embryogenesis. To the contrary, pathological angiogenesis is associated with multiple diseases including cancers [63]. Highly malignant tumors can induce angiogenesis to provide sufficient oxygen and nutrients for themselves [64]. Additionally, angiogenesis also provides paths for cancer cells to metastasize distant tissues [65]. In tumor microenvironment, tumor and host cells release pro-angiogenic and anti-angiogenic factors. The pro-angiogenic factors include transforming growth factor (TGF), vascular endothelial growth factor (VEGF), tumor necrosis factor (TNF), epidermal growth factor (EGF), and so on, and there is a fine balance between them. When the balance is skewed to the pro-angiogenic state, tumor shifts from a dormant state to a hyper-vascularized state [66]. Since angiogenesis plays an important role in the metastatic behaviors of cancer cells, natural products obtained from Chinese medicines targeting on tumor-induced angiogenesis have been regarded as promising agents to metastatic cancers.

Berberine has been shown to exhibit a significant inhibition on the migratory and invasive ability of hepatocellular carcinoma cells. Except for downregulation of uPA, berberine also inhibits angiogenesis through suppressing inhibitor of differentiation/DNA binding (Id-1) via HIF-1α/VEGF pathway [67, 68]. Cucurbitacin B (CuB), a plant triterpenoid, obtained from Cucurbitaceae family has been shown to inhibit the metastasis and angiogenesis of breast cancer MDA-MB-231 and 4T1 cells via downregulating VEGF/FAK/MMP-9 signaling [69]. Recently, a study of artesunate, a normal traditional Chinese medicine, has been conducted to investigate the anti-metastatic effects of artesunate on cervical cancer. The results demonstrated that artesunate inhibits cancer cell migration and invasion in vitro through suppressing HOTAIR and COX-2-mediated angiogenesis [70]. Likewise, similar inhibitory effects have also been observed in various extracts from Chinese medicines. The aqueous extract of Coptidis Rhizoma, a traditional Chinese medicinal herb with a long history, was observed to inhibit hepatocellular carcinoma cell migration both in vitro and in vivo through suppressing Rho/ROCK signaling pathway and inhibiting VEGF secretion [71, 72]. Gardeniae Fructus, a fruit obtained from *Gardenia jasminoides* Ellis, has been applied as traditional medicine and possesses various health benefits against multiple diseases. A recent study has shown that the ethanol extract of baked Gardeniae Fructus has an inhibitory effect on the angiogenic
and metastatic ability of melanoma cells both in vitro and in vivo via inhibiting the release of pro-angiogenic factors [73]. Lophatheri Herba, a dried leaf obtained from Lophatherum gracile Brongn, possesses inhibitory effects on the metastasis and angiogenesis of malignant cancer cells at noncytotoxic doses. It has been shown that ethanol extract of Lophatheri Herba (ELH) can inhibit the cancer cell metastasis both in vitro and in vivo through suppressing tumor-induced angiogenesis via decreasing the pro-angiogenic factors [74]. As an ancient Chinese medicine formula, Gegen Qinlian decoction was reported to suppress the neoangiogenesis in xenografted renal carcinoma cell tumor through inhibiting the enzyme activity of MMP-2 [75].

5. Anoikis regulation of circulating tumor cells

Anoikis, known as detachment-induced apoptosis, is a process of programmed cell death [76]. It can block metastasis by eliminating circulating cancer cells. However, in highly metastatic cancer cells, anoikis can be overcome and cancer cells can survive in a circulating condition until reaching a proper secondary site [77]. Anoikis is controlled by Bcl-2 family proteins. The pro-apoptotic proteins, such as Bax and the anti-apoptotic proteins, such as Bcl-2 and Bcl-xL, interact during anoikis [78]. In addition, anti-apoptotic protein myeloid leukemia cell sequence-1 (MCL-1) and caveolin-1 (CAV-1) have also been demonstrated to suppress anoikis [79]. Anoikis has become potential therapeutic target, and discovering new natural products obtained from Chinese medicines targeting anoikis is of great interest [80].

The anti-metastatic study of arctigenin on colorectal cancer has been recently conducted. Arctigenin can induce anoikis via MAPKs signaling, inhibit EMT through increasing E-cadherin and decreasing N-cadherin, vimentin, β-catenin, and Snail, and downregulate MMP-2/9, so that inhibition on the tumor cell migration and invasion both in vitro and in vivo was achieved [81]. Imperatorin, an active furanocoumarin component obtained from the root of Angelica dahurica, has been demonstrated to sensitize anoikis by downregulating Mcl-1 protein and upregulating Bax in lung cancer [82]. As a major dietary flavonoid, quercetin was reported to induce apoptosis through the MAPKs pathway, regulate EMT markers including E- cadherin, N-cadherin, β-catenin, and snail and modulate MMPs and TIMPs in colorectal cancer [83]. Curcumin, a compound derived from the rhizome of turmeric, was reported to inhibit the migratory and invasive ability of lung cancer cells through sensitizing anoikis, which was associated with downregulation of Bcl-2 [84]. Such anoikis regulation was also observed in lung cancer cells challenged other single compounds obtained from Chinese medicine, such as artonin E [85], ecteinascidin 770 [86], renieramycin M [87], Oroxylin A [88], and so on. In addition, regulation on anoikis was also observed in tumor cells treated with various extracts from Chinese medicines. Annona muricata Linn from Annonaceae family has long been applied to treat different diseases. Recently, its leaf aqueous extract (B1 AMCE) has been reported to exhibit anti-metastatic property in breast cancer [89]. B1 AMCE can significantly suppress the metastasis of 4T1 breast cancer cells in vitro and in vivo via inducing their apoptosis. The aqueous extract of Andrographis paniculata was demonstrated to inhibit anoikis resistance in esophageal cancer [89]. The bibenzyl compounds from Dendrobium pulchellum
[90] and the mixture of flavonoids extracted from Korean Citrus aurantium have been shown to induce apoptosis and inhibit metastasis of lung cancer cells [91].

6. Regulation of miRNA-mediated gene expression

As negative regulators of gene expression, microRNAs (miRNAs) have been shown to modulate multiple biological functions, such as immune response, metabolism, and metastasis [92]. miRNAs mediate the expression of target protein through degrading its mRNA or inhibiting the translation of mRNA via binding to mRNA three prime untranslated region (3’UTR). There is a dual action of miRNAs in cancers, either functioning as cancer promoters or inhibitors. Nearly, all human tumors have the characteristic of miRNAs dysregulation [93]. Since miRNAs play an important role in the metastatic behaviors of cancer cells, developing natural products obtained from Chinese medicines targeting miRNAs may be a promising strategy to treat metastatic cancers.

Recently, the anti-metastatic property of arsenic trioxide (ATO) in chondrosarcoma has been elucidated. It was reported that ATO attenuate the metastasis of chondrosarcoma cells through inhibit miR-125b/Stat3 axis [94]. As a common antioxidant obtained from cruciferous plants, sulforaphane has been reported to inhibit the migratory and invasive ability of lung cancer both in vitro and in vivo. This action is mediated by miR-616-5p [95]. In addition, ginsenoside Rd (Rd), one of the chemical compounds in Panax Notoginseng Saponins, has been investigated for its anti-metastatic property recently. The results showed that Rd treatment inhibited the migratory and invasive ability of breast cancer both in vitro and in vivo via suppressing miR-18a-mediated Smad2 expression [96].

7. Conclusion and future challenges

Accumulating evidence has demonstrated that Chinese medicine is an excellent source for the development of novel therapies for metastatic cancer. As mentioned above, the molecular mechanisms underlying the effects of potential anti-invasive and metastatic Chinese medicines include suppression of EMT (e.g., epithelial and mesenchymal markers), suppression of proteases expression (e.g., MMPs, uPA and Rho GTPases), suppression of cancer-induced angiogenesis (e.g., pro-angiogenic and anti-angiogenic factors), anoikis regulation of circulating tumor cells (e.g., pro-apoptotic and anti-apoptotic proteins), and regulation of miRNA-mediated gene expression (e.g., miR-125b, miR-616-5p and miR-18a). The chapter summarized the potential anti-invasive and metastatic drug candidates, which provided scientific evidence for clinically used Chinese medicines in the field of cancer therapy. Understanding of the underlying molecular mechanisms may in turn lead to discovery and development of novel anticancer drugs. Although these findings show the anti-metastatic potential of Chinese medicines, studies to evaluating the marked efficacies and determining the appropriate therapeutic doses of anti-metastatic Chinese medicines in animal models and clinical trials are still
badly necessary in the future. In addition, the modern techniques such as nanoparticles which may improve the anti-cancer properties via better cellular uptake, enhanced bioavailability, and localization to targeted sites should also be studied in the future.

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