REVIEW ARTICLES

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Anisodus tanguticus in Cancer Research: A Review of Traditional Use, Phytochemistry, Extraction Methods, and Preclinical Antitumor Evidence

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Anisodus tanguticus (Maxim.) Pascher has been documented in Tibetan ethnomedicine. Traditional records indicate that *A. tanguticus* has traditionally been used to relieve pain, treat parasitic infections, and heal skin wounds caused by viral infections. *A. tanguticus* is rich in tropane alkaloids, including anisodamine, scopolamine, and atropine, which are pharmacologically active constituents with well-known parasympatholytic effects. These alkaloids have shown promise in controlling cancer cell proliferation and metastasis, with preclinical studies indicating antitumor activity against liver, breast, and colorectal cancers. The extraction of *A. tanguticus* traditionally involves methods such as juice pressing or boiling; however, modern techniques like ultrasonic, reflux, and supercritical fluid extraction have enhanced alkaloid yield and quality. While the pharmacological properties of *A. tanguticus* suggest that some constituents of *A. tanguticus* may have preclinical antitumor relevance, most studies remain preclinical, and clinical data is limited. This review highlights the need for further pharmacological, toxicological, and translational studies. Current evidence suggests that *A. tanguticus* and several of its constituents exhibit preclinical antitumor activity; however, their clinical relevance remains uncertain, and further pharmacological, toxicological, and clinical validation is required. This narrative review summarizes the traditional use, phytochemical composition, extraction methods, antitumor-related findings, and proposed mechanisms of *A. tanguticus*, while highlighting the need for further pharmacological, toxicological, and translational studies.

Keywords: Antineoplastic Agents • Medicine, Tibetan Traditional • Alkaloids • Tumor Cells, Cultured • Drug Discovery

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Introduction

Cancer incidence continues to rise in the 21st century. Data published by the International Agency for Research on Cancer estimate that there were 29 million cancer cases and 9.96 million cancer-related deaths worldwide in 2023 [1]. In recent decades, advances in oncology have led to diverse treatment modalities, including surgery, radiotherapy, chemotherapy, hormonal agents, molecularly targeted drugs, and immunotherapies [2,3]. Each of these approaches has improved survival in certain cancers. However, they all are associated with important limitations, including resistance, systemic toxicity, and immune-related adverse events [4-6]. This suggests the need for better treatment options, and Chinese herbal medicine may be one promising choice. In recent years, Chinese herbal medicine has attracted increasing attention because of its long history of medicinal use [7]. Its herbal remedies are associated with fewer toxic adverse effects and a lower likelihood of causing drug resistance; however, these effects may vary depending on the specific context, and further studies are needed to confirm these findings [7,8]. Notably, there has been substantial progress in using these herbs to treat diabetic complications [9], antiviral diseases, and other conditions [10,11]. Herbs containing bioactive compounds such as triptolide in *Tripterygium wilfordii* [12], matrine in *Sophora flavescens* [13], and berberine in *Coptis chinensis* [14] exhibit antitumor activity. Some herbal compounds have shown antitumor activity in experimental studies and may act through multiple mechanisms [15-17], inducing apoptosis [12,13,18], inhibiting tumor metabolism [19-21], reducing inflammation [22,23], and minimizing infection risks [24]. However, the safety, efficacy, and translational relevance of herbal medicines vary across compounds, and clinical contexts and should not be generalized [7,8,24].

Tibetan medicine is a distinct traditional medical system with a long history of herbal medicine use, known for its diversity and rich resources. It encompasses a wide range of medicinal resources and applications [25-27]. In eastern Tibet, Tibetans commonly use the roots and seeds of *Anisodus tanguticus* (Maxim.) Pascher to alleviate toothaches and stomachaches, treat parasitic infections, and heal skin wounds caused by viral infections. This Tibetan medicine, *A. tanguticus,* is often used in combination with other herbal medicines for its anti-infective, antiparasitic, anti-inflammatory, analgesic, antitumor, and various other therapeutic effects [28-30]. These therapeutic effects are thought to be related to the diverse bioactive constituents of *A. tanguticus*. Its primary active ingredients are alkaloids, which are commonly used in clinical settings as parasympathetic inhibitors [31,32]. Among them, anisodamine has been widely studied with respect to its chemical properties, pharmacokinetics, toxicity, and clinical applications [33]. However, the pharmacological activity of these tropane alkaloids is also associated with toxicity. *A. tanguticus* has been recognized as a poisonous medicinal plant in Tibetan ethnomedicine [34]. Its toxicity is mainly related to tropane alkaloid-associated anticholinergic poisoning, and inappropriate ingestion or use can cause serious poisoning events. A reported outbreak in Maqin County, Qinghai Province, China, involved 10 patients and 1 death, further highlighting the public health risks associated with *A. tanguticus* exposure [35].

Ethanol and ammonia liquor are commonly used for extraction, with silica gel column chromatography, high-performance liquid chromatography with diode-array detection (HPLC-DAD), preparative chromatography, mass spectrometry, and nuclear magnetic resonance being used for separation and structural identification. These methods have led to the isolation of compounds such as scopolamine, anisodine, caffeoylputrescine, fabiatrin, scopolin, anisodamol E, and bellaradine [36-42]. Recent phytochemical studies have also identified new indolizidine- and pyrrolidine-type alkaloids with anti-angiogenic activity from *A. tanguticus* [37]. Variations in the source of *A. tanguticus*, extraction methods, and separation techniques account for the differences in the compounds obtained [36]. Recent studies have shown that several compounds from *A. tanguticus* exhibit anticancer potential. Anisodamine inhibits liver cancer progression [43-46]. Scopoletin has shown promise in inhibiting various tumors, including cervical cancer, cholangiocarcinoma, leukemia, non–small cell lung cancer, and colorectal cancer [47-51]. Atropine suppresses colorectal cancer cell proliferation [33]. These findings suggest that several constituents of *A. tanguticus* exhibit preclinical antitumor activity and warrant further experimental investigation.

Recent reviews have summarized the traditional uses, phytochemistry, and general pharmacology of *A. tanguticus*, including a recent review on the Tibetan medicinal plant tangchong [52]. However, the currently available literature has not specifically integrated the preclinical antitumor evidence, extraction and isolation strategies, and the translational limitations related to toxicity and clinical relevance. Therefore, in this review, we summarize the traditional use, phytochemical composition, extraction methods, and preclinical antitumor evidence of *A. tanguticus* and its major constituents, while highlighting current limitations in toxicity evaluation, clinical relevance, and translational research.

Antitumor Effects of *A. tanguticus* as a Traditional Tibetan Medicine

A. tanguticus has been used as a medicinal plant in Tibetan ethnomedicine [34,53,54]. Traditionally, its roots and seeds are primarily used to relieve pain, eliminate parasites, and treat skin wounds caused by viral infections [28,55,56]. Common

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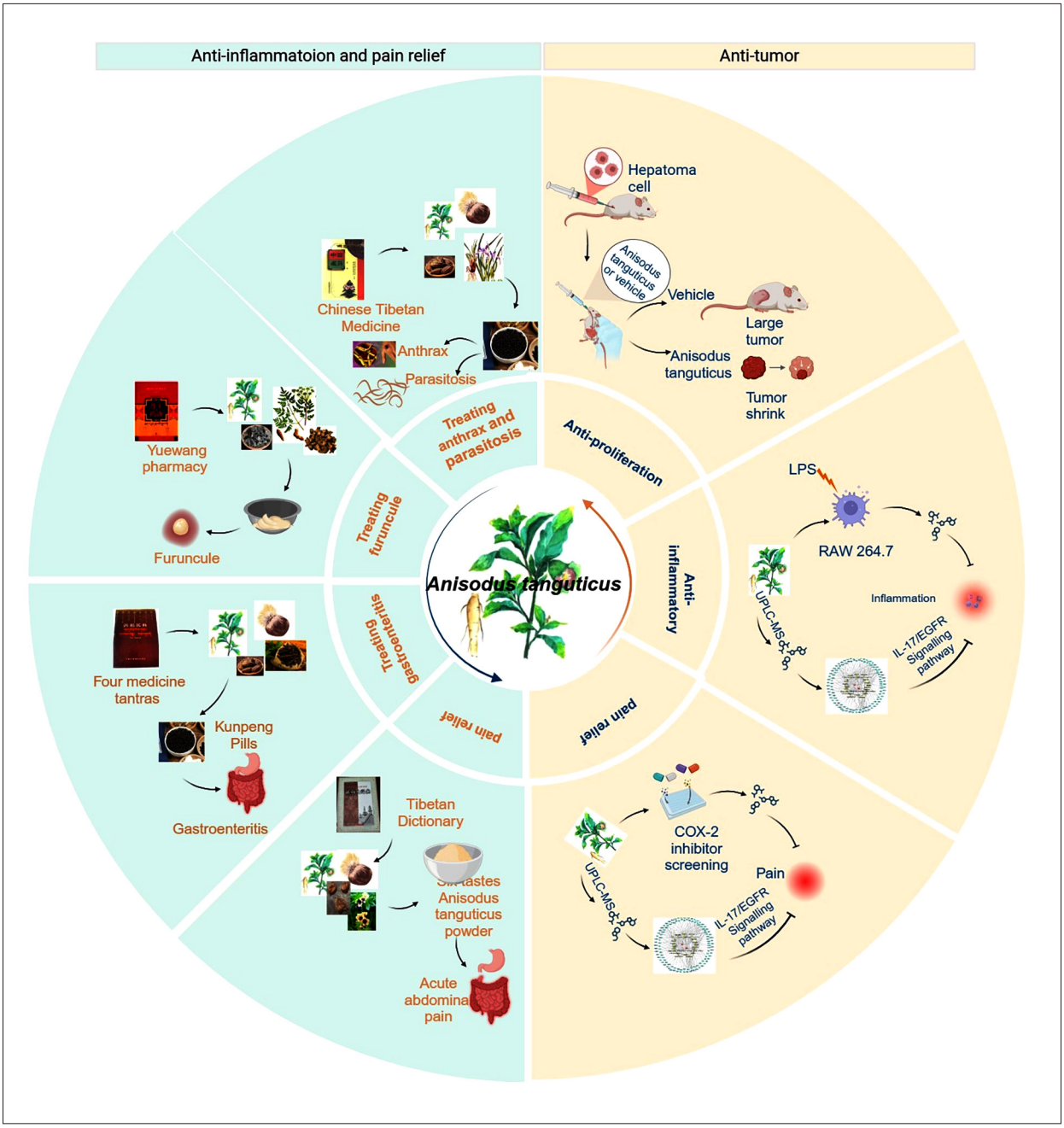

Figure 1. Traditional uses and preclinical antitumor activity of *Anisodus tanguticus*. This plant, used in Tibetan medicine, relieves pain, eliminates parasites, and treats skin wounds. It is commonly applied as external preparations, tablets, or poultices, often combined with other herbs. Traditional use suggests anti-inflammatory and analgesic properties.

applications of *A. tanguticus* include freshly pounded herbs for external use, as well as tablets, poultices, and other formulations [56]. Its combination with various herbal constituents typically yields favorable therapeutic outcomes. Records from *Chinese Tibetan Medicine* indicate that a prescription of *A. tanguticus* root ointment, combined with musk, benzoin, chebula, qidanga, and Malus seed, can be used to treat anthrax, boils, poisoning, infected ulcers, malignant sores, roundworm disease, and other illnesses, resulting in improved therapeutic effects [56]. Additionally, it is noted in *Yuewang Pharmacy* that *A. tanguticus*, along with Qiang Wu, sour mould, hairy calyx multiflora aconite, calf cow dung, poplar bark, *Berberis* medium bark, peppercorns, dog dung, and wicker botanic welfare, can effectively treat furunculosis [29]. Furthermore, the *Four Medicine Tantras* indicates that Kun-peng pills, which contain *A. tanguticus*, are effective in treating acute gastroenteritis [57].

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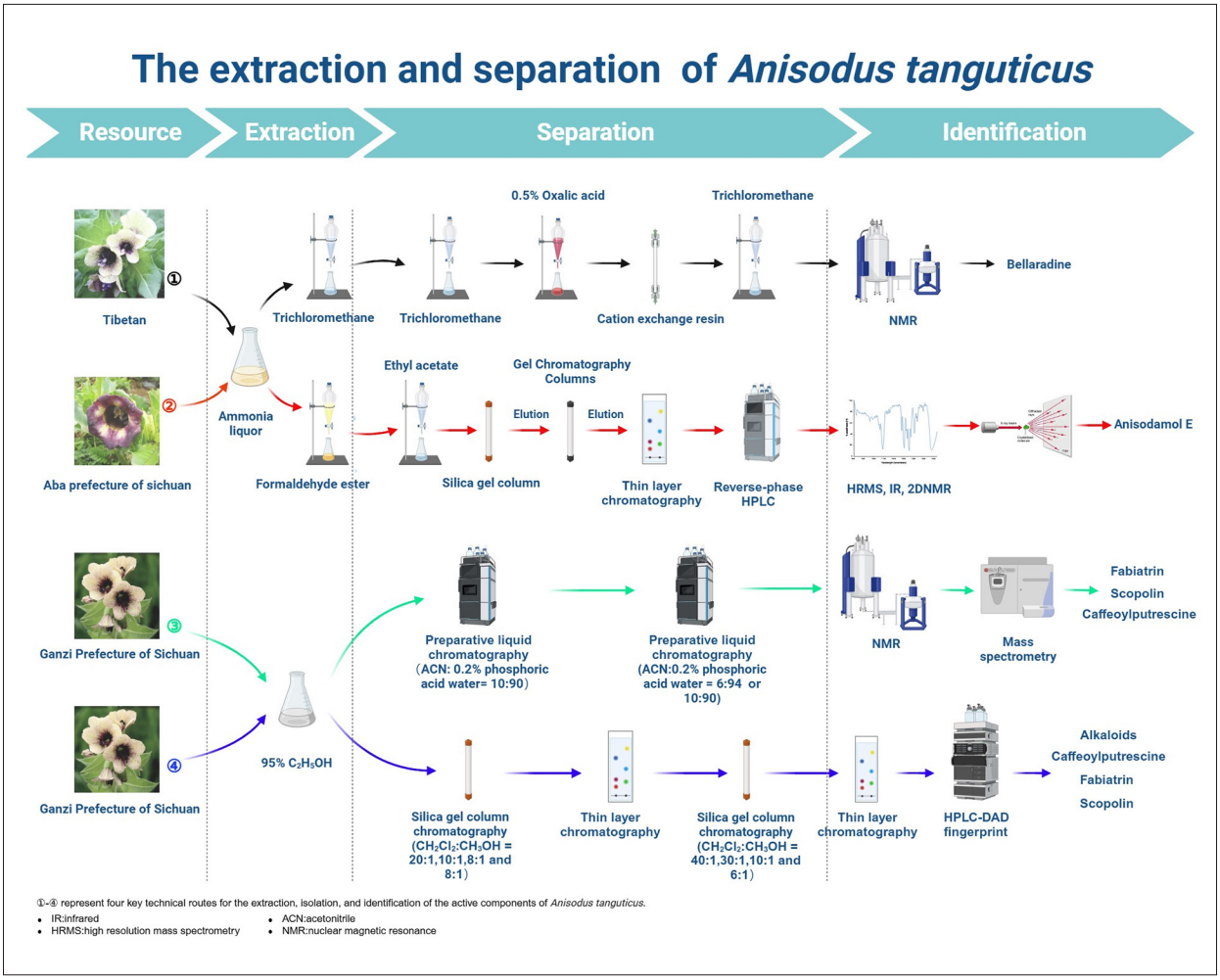

Figure 2. Main techniques used for the extraction, separation, and structural identification of constituents from *Anisodus tanguticus*. The figure summarizes commonly used extraction approaches, chromatographic separation methods, and analytical techniques applied for compound characterization.

In pain management, *A. tanguticus* has demonstrated promising results. For instance, the six-flavored *A. tanguticus* powder is used to alleviate pain from acute abdominal conditions, as noted in the *Tibetan Dictionary* [58]. *Chinese Tibetan Medicine* also documents that *A. tanguticus* can effectively cure toothaches [56]. These findings suggest that traditional prescriptions of *A. tanguticus* possess anti-inflammatory and pain-relieving properties. Tan et al conducted a network pharmacology analysis to examine the anti-inflammatory and analgesic effects of *A. tanguticus*, focusing on the epidermal growth factor receptor (EGFR) tyrosine kinase inhibitor resistance signaling pathway and the interleukin-17 (IL-17) signaling pathway [59]. Patients with tumors typically exhibit clinical symptoms related to inflammation and pain [60,61]. Given its reported anti-inflammatory and analgesic properties, *A. tanguticus* may be of interest for supportive symptom-related research in oncology; however, direct clinical evidence is lacking. Zhang et al demonstrated that the Yushu *A. tanguticus* (Tang Chong Na Bao) extract significantly inhibited the growth of liver tumors in mice, with an inhibition rate of 41.27% [30] (**Figure 1**). This finding suggests that the traditional Tibetan medicine *A. tanguticus* may have preclinical antitumor activity. However, currently, there are few studies on its antitumor effects, and the mechanism of action remains unclear and requires further investigation.

Extraction, Isolation, and Identification of Major Constituents of *A. tanguticus*

In the last decade, many researchers have applied different chemical techniques for the extraction, isolation, and structural characterization of the ingredients in *A. tanguticus*. The reagents commonly used for extraction are primarily ethanol and ammonia liquor (**Figure 2**). The techniques used for isolation mainly include chromatography, while identification techniques primarily consist of nuclear magnetic resonance, modern

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Table 1. Extraction, separation, and identification of major constituents isolated from *Anisodus tanguticus*.

Resource	Extraction and separation methods	Identification method	Compound	Ref.
Ganzi Prefecture, Sichuan Province	**Extraction:** 95% ethanol **Separation:** column chromatography with a mobile phase of acetonitrile-30 mmol/L sodium acetate buffer and silica gel column chromatography and thin-layer chromatography alternately	HPLC-DAD fingerprinting	Scopolamine, atropine, anisodine, anisodamine, caffeoylputrescine, fabiatrin, and scopolin	[38,39]
Ganzi Prefecture, Sichuan Province	**Extraction:** 95% ethanol **Separation:** preparative chromatography (acetonitrile: 0.2% phosphoric acid in water=6: 94)	NMR and mass spectrometry	A variety of water-soluble compounds	[40]
Aba Prefecture, Sichuan Province	**Extraction:** ammonia liquor **Separation:** silica gel column chromatography, gel column chromatography, and thin-layer chromatography	Modern spectroscopic techniques (HRMS, IR, 2D NMR)	The new compound Anisodamol E	[41]
Tibet region	**Extraction:** ammonia liquor **Separation:** repeated extraction using trichloromethane and 0.5% oxalic acid, followed by separation on a cation exchange column	NMR	Special compound Bellaradine	[42]

Table 1 was compiled by the authors based on the cited references. Abbreviations: HPLC-DAD, high-performance liquid chromatography with diode-array detection; NMR, nuclear magnetic resonance; HRMS, high-resolution mass spectrometry; IR, infrared spectroscopy; 2D NMR, 2-dimensional nuclear magnetic resonance.

spectroscopic methods (high-resolution mass spectrometry, infrared spectroscopy, and 2-dimensional nuclear magnetic resonance), mass spectrometry, and HPLC-DAD chromatography. Various researchers have utilized different techniques to obtain a range of compounds (**Figure 2**). In 2014, Jiang et al extracted *A. tanguticus* using 95% ethanol. The extraction process involved column chromatography, employing a mobile phase of acetonitrile and 30 mmol/L sodium acetate buffer. The separated components were further analyzed using thin-layer chromatography, resulting in the isolation of individual compounds. These compounds underwent HPLC-DAD fingerprinting for structural characterization, yielding various compounds, including scopolamine, atropine, and anisodine [38]. In 2017, Jiang et al revised the isolation method by alternating between silica gel column chromatography and thin-layer chromatography, ultimately obtaining various compounds, including caffeoylputrescine, fabiatrin, and scopolin [39]. In 2022, Jin et al used ethanol for extraction and preparative chromatography (acetonitrile: 0.2% phosphoric acid in water = 6: 94) for multiple separations [40]. Finally, they identified the structures using nuclear magnetic resonance and mass spectrometry to obtain a variety of water-soluble compounds. In addition, in 2022, Zhao et al used ammonia for extraction, as well as silica gel column chromatography, gel column chromatography, and thin-layer chromatography for separation. Modern spectroscopic techniques (high-resolution mass spectrometry, infrared spectroscopy, and 2-dimensional nuclear magnetic resonance) were then used for structural characterization, leading to the discovery of the new compound anisodamol E [41] (**Figure 2**). In 2023, Hu et al followed up on this work with repeated extraction using trichloromethane and 0.5% oxalic acid, followed by separation on a cation exchange column. Finally, nuclear magnetic resonance structural characterization was performed to obtain the special compound bellaradine [42].

Differences in Source, Extraction Methods, and Structural Identification of *A. tanguticus*

The differences in these studies include the source of *A. tanguticus*, the extracts, separation methods, mobile phases, and structural identification techniques, as shown in **Table 1**. Jiang et al and Jin et al primarily used *A. tanguticus* from Ganzi Prefecture, Sichuan Province, while Zhao et al mainly sourced it from Aba Prefecture, Sichuan Province, and Hu et al obtained it from the Tibet region. The variations in separation methods were primarily due to differences in chromatography and the mobile phases used. As shown in **Table 2**, anisodamine, atropine, and scopoletin are the primary substances found in *A. tanguticus* extracts. Several major constituents of *A. tanguticus* are pharmacologically associated with cholinergic receptor signaling [62,63], which is known to promote cancer

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Table 2. Main constituents reported from *Anisodus tanguticus*.

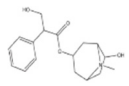
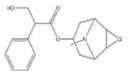
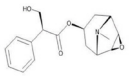
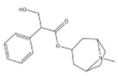
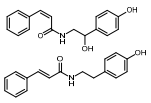
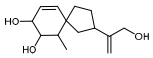
Name	Structure	Ref.
Anisodamine		[40]
Atropine		[40]
Scopolamine		[41]
Hyoscyamine		[41]
Amide		[41]
Nor-vetispirane sesquiterpenoid		[41]

Table 2 was compiled by the authors based on the cited references, and the chemical structures were redrawn by the authors.

progression [64]. Because several identified constituents of *A. tanguticus* have been reported to modulate pathways relevant to tumor biology, the plant remains of interest for further preclinical antitumor investigation [31,33,43].

Preclinical Antitumor Effects of Anisodamine

Anisodamine attenuates renal and cardiac damage by inhibiting endoplasmic reticulum stress–associated TXNIP/NLRP3 inflammasome activation [65]. Further studies revealed that anisodamine dose-dependently inhibits NLRP3 mRNA and protein levels in a mouse model of hepatocellular carcinoma, suppressing inflammasome activation and subsequently inhibiting the maturation and secretion of interleukin (IL)-18 and IL-1β [43,66,67]. In hepatocellular carcinoma, breast tumors, and fibrosarcoma, NLRP3 facilitates tumor growth and metastasis through the release of IL-1β. However, in colorectal tumors, IL-18 released by NLRP3 has been shown to enhance the tumoricidal activity of natural killer cells [43,68-70] (**Figure 3**). Therefore, further investigation is required to elucidate the direct regulatory mechanism of anisodamine on the NLRP3 inflammasome to gain a more precise understanding of its immunomodulatory functions within the tumor microenvironment. Additionally, low NLRP3 expression has been shown to increase interferon-γ (IFN-γ) and IL-27 levels while reducing IL-4 and tumor necrosis factor α levels, which are closely associated with the balance of Th1/Th2 immune responses [43,71-73]. However, whether anisodamine maintains the Th1/Th2 balance by inhibiting NLRP3 inflammasome activation requires further evidence for confirmation. Moreover, the inhibitory effect of anisodamine on the NLRP3 inflammasome is dose-dependent [43]. As these current studies are all preclinical in nature, they primarily focus on short-term experimental observations, leaving the temporal dynamics and precise dose-dependency yet to be fully elucidated.

Ma et al reported that in SKBR3 cells treated with anisodamine, the proportion of cells in the G0/G1 phase increased, with minimal impact on the apoptosis rate. This finding is consistent with the observed upregulation of cAMP expression, indicating that anisodamine likely suppresses tumor cell proliferation by increasing cAMP levels [74]. Cholinergic receptors play a crucial role in regulating cAMP levels [75]. Extensive evidence indicates that anisodamine significantly inhibits the M3 muscarinic acetylcholine receptor, a subtype of cholinergic receptors [31,47,76]. However, these findings are all based on preclinical studies. The potential antitumor effects of anisodamine, as an M3 receptor antagonist, still require further research and validation (**Figure 3**).

Preclinical Antitumor Effects of Scopoletin

In cervical cancer [47], cholangiocarcinoma [77], leukemia [78], non–small cell lung cancer [79], and colorectal cancer cell lines [80], scopoletin primarily exerts its effects by regulating the phosphatidylinositol 3-kinase/protein kinase B/mammalian target of rapamycin (PI3K/AKT/mTOR) signaling pathway [81] (**Figure 4**). This regulation leads to G0/G1 phase

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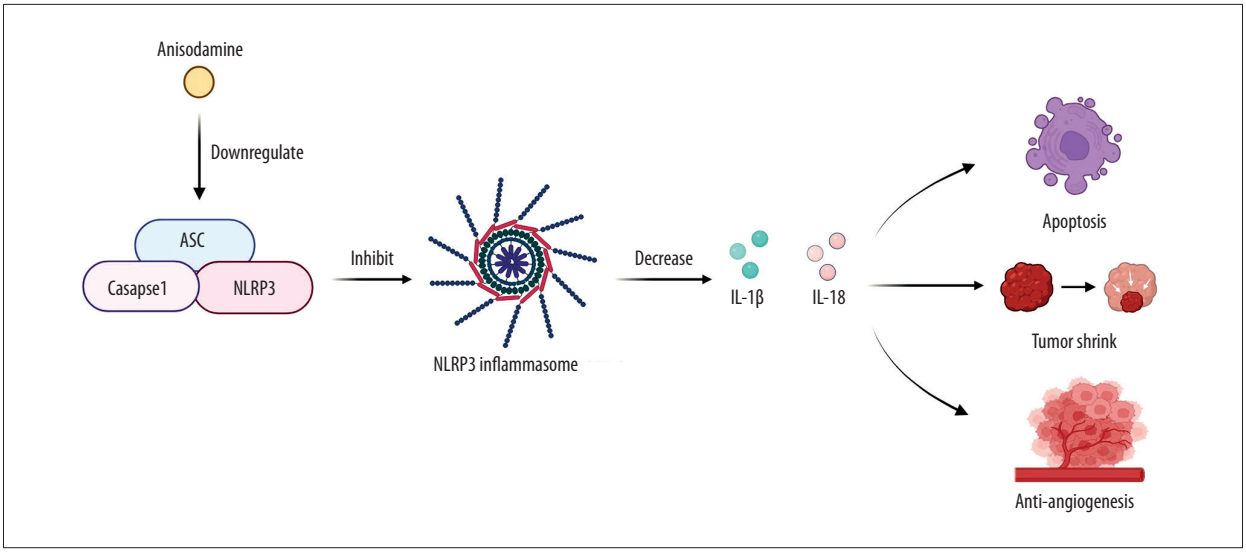

Figure 3. Schematic summary of the reported preclinical antitumor mechanisms of anisodamine. The figure illustrates the main signaling pathways and biological processes that have been associated with anisodamine-mediated inhibition of tumor cell proliferation and tumor-related inflammation.

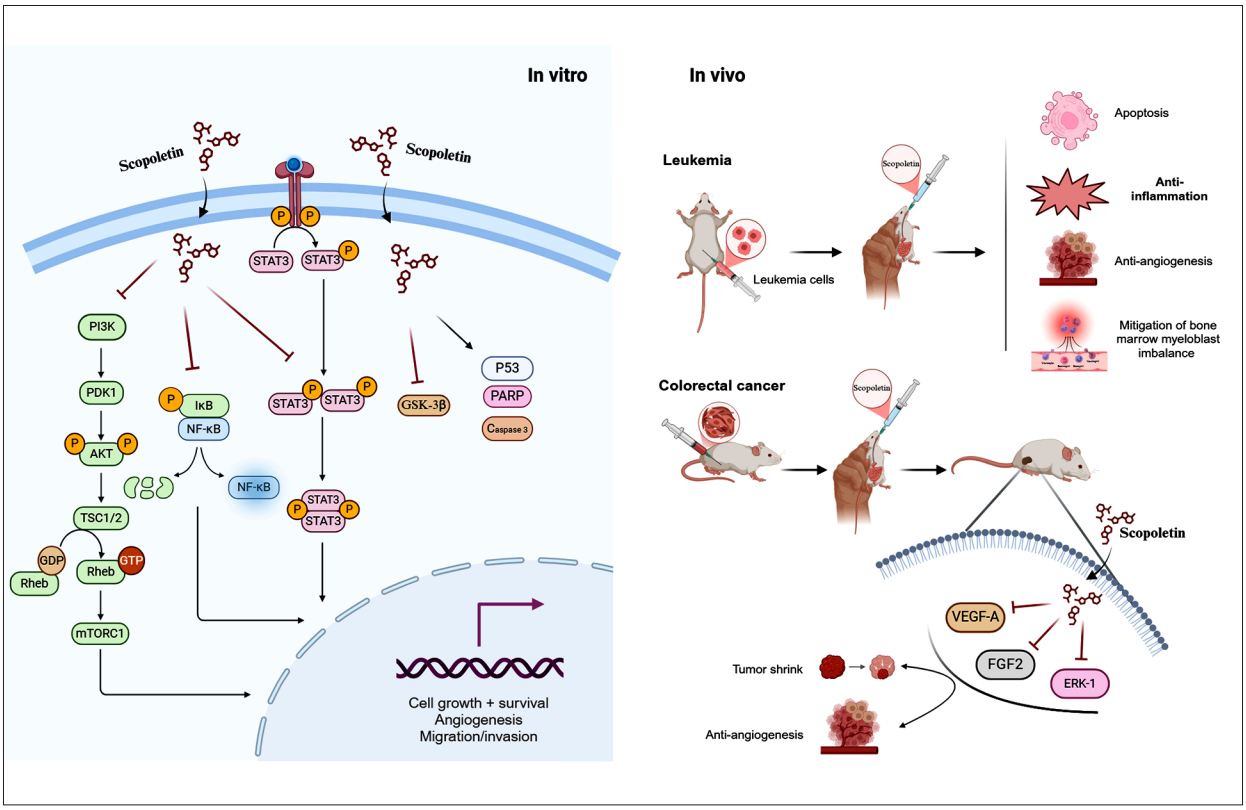

Figure 4. Schematic summary of the reported preclinical antitumor mechanisms of scopoletin, including effects on apoptosis, cell-cycle arrest, migration, and angiogenesis-related signaling pathways.

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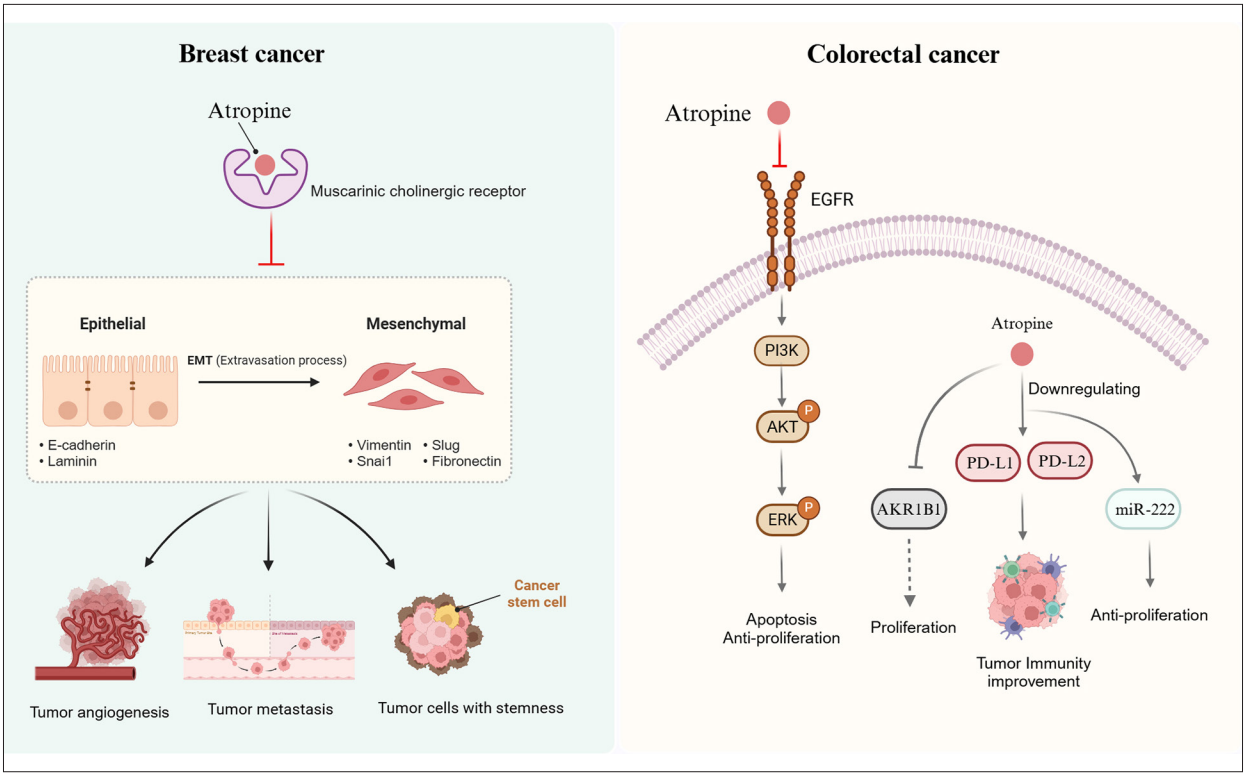

Figure 5. Schematic summary of the reported preclinical antitumor mechanisms of atropine. The figure illustrates the signaling pathways and tumor-related processes associated with atropine, including regulation of epidermal growth factor receptor (EGFR)/protein kinase B (AKT)/extracellular signal-regulated kinase (ERK) signaling, immune checkpoint-related markers, and metastatic behavior.

arrest, followed by apoptosis induction through the activation of caspase-3 and caspase-8. Additionally, in cholangiocarcinoma [77] and leukemia cells [78], scopoletin further inhibits tumor cell progression by blocking the NF-κB signaling pathway and downregulating VEGF expression, thereby inhibiting tumor angiogenesis and suppressing metastasis (**Figure 4**). In non–small cell lung cancer and colorectal cancer cell lines, scopoletin regulates the RAS-RAF-MEK-ERK and STAT3 signaling pathways to inhibit tumor progression [79,82,83] (**Figure 4**). In cholangiocarcinoma cells, scopoletin significantly inhibits tumor cell migration by suppressing NQO1 enzyme activity and reducing the MMP9/TIMP1 ratio [77]. Furthermore, in addition to the PI3K signaling pathway, scopoletin may also promote tumor apoptosis through the JAK/STAT3 pathway [77,84] (**Figure 4**). Notably, in leukemia cells, scopoletin upregulates tumor suppressive genes such as TRP53, SOCS1, and CSF3, while downregulating the expression of procancer genes such as AKT1 and BCL2. This mechanism has not been observed in other cell lines [78]. Moreover, scopoletin induces apoptosis in A375 human melanoma cells by downregulating cyclin D1, suppressing the proliferation of nuclear antigen, survivin, and STAT3, and upregulating the expression of p53 and caspase-3 [80] (**Figure 4**). In the Hepa cell line of cervical cancer, scopoletin shows selective inhibition of tumor cells, with minimal toxicity to normal cells, suggesting selective antitumor activity in this experimental setting [47].

Overall, scopoletin regulates tumor cells through multiple signaling pathways and targets. While the PI3K signaling pathway is widely present across various tumor cell lines, other signaling pathways exhibit variability depending on the specific cell line. Moreover, some targets, such as ERK1, vascular endothelial growth factor-A, and FGF-2, have been predicted through computational modeling [79]. Additionally, most studies on scopoletin in cervical cancer and cholangiocarcinoma [47,77] primarily focus on in vitro experiments. These antitumor activity findings are all based on preclinical studies. Therefore, conducting additional in vivo and in vitro experiments is essential to validate the mechanisms of scopoletin and assess its therapeutic efficacy across various tumor cell lines [85].

Preclinical Antitumor Effects of Atropine

Atropine inhibits the proliferation of colorectal and breast cancer cells. It also has similarities and differences in its mechanism of action for different cancers. The similarity is that it suppresses cancer growth, proliferation, and metastasis by inhibiting

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the EGFR/AKT/ERK signaling pathway [86,87] (**Figure 5**). The difference is that atropine induces apoptosis in colorectal cancer cells by reducing the expression of PD-L1 and PD-L2, resulting in a reduction of 20.1% [33,88]. It inhibits metastasis in breast cancer cells by blocking muscarinic acetylcholine receptors (mAChR) (**Figure 5**). The first molecular mechanism is that atropine blocks the binding of autoantibodies to mAChR, which in turn reduces the expression of vascular endothelial growth factor-A [89,90] (**Figure 5**). The second proposed mechanism is the inhibition of epithelial-mesenchymal transition during tumorigenesis, which reduces the half-maximal inhibitory concentration values of breast cancer cell lines by more than 10 μL [91,92]. Additionally, leukemia K562 cells express alpha-7 nicotinic acetylcholine receptor (α7-nAChR), and atropine, an antagonist of the α7-nAChR, inhibits leukemia cell proliferation [93]. The antitumor activity of atropine has been observed exclusively in preclinical settings. Consequently, it is not currently recommended as a standalone therapeutic agent. Instead, it is administered in combination with other tumor treatments. Research has shown that atropine can help prevent the pain and discomfort associated with transurethral resection of bladder tumors, a mechanism that is linked to its ability to block mAChR. Additionally, atropine can be used alongside cystectomy for bladder tumors to enhance the therapeutic effect [94]. Atropine can also be used in combination with the method of acupuncture point injection for the treatment of recalcitrant tumor eruptions [95]. It is important to note that atropine crosses the blood brain barrier and can cause a central anticholinergic syndrome characterized by drowsiness, disorientation, and hallucinations. Therefore, the dose of atropine needs to be investigated in clinical trials [96].

Discussion and Future Directions

Based on the preclinical findings summarized above, we discuss the specific barriers impeding the translation of *A. tanguticus* compounds into clinical oncology and propose potential strategies to address them in the following sections.

Challenges in Extraction and Standardization

Although researchers have successfully isolated various compounds from *A. tanguticus*, current extraction methods present several significant challenges. The efficiency of existing techniques is often suboptimal and can be accompanied by high reagent consumption and excessive costs. In addition, variability in the source of *A. tanguticus* can lead to inconsistencies in the dosage and composition of isolated compounds, underscoring the necessity for improved quality control and standardization of raw materials [36,97]. Additionally, certain compounds are susceptible to degradation during extraction or storage, leading to the loss of active ingredients [98].

To address the issue of low extraction efficiency, advanced techniques such as ultrasound-assisted extraction or supercritical fluid extraction could be implemented, which have been shown to significantly enhance extraction yields while reducing solvent usage [99]. To ensure the quality and consistency of *A. tanguticus*, standardizing cultivation conditions, harvest times, and collection methods is essential to minimize environmental variations that affect compound composition [100]. Furthermore, adopting cold extraction methods and low-temperature storage techniques can help mitigate compound degradation, thereby preserving the stability and efficacy of the active ingredients [101,102]. Studies suggest that ammonia-based extraction may be useful for enriching alkaloid fractions in some experimental settings, although the optimal extraction strategy depends on plant source, target constituents, and downstream analytical methods. For separation, various column chromatographic methods can be used, with the polarity of the mobile phase varying from low to high for multiple elution separations. The structural identification can leverage the commonly used and powerful nuclear magnetic resonance technique. In specific experiments, the selection should be made based on the actual experimental conditions.

Challenges in Understanding the Antitumor Effects of Whole-Herb and Multi-Herb Formulations

Current research on *A. tanguticus* has focused mainly on its isolated active compounds, with little attention paid to the antitumor efficacy of the whole herb or its role in combinatorial treatment strategies. Additionally, the effects of other herbal components within multi-herb formulations, as well as the potential synergistic interactions between individual components from different herbs, warrant further exploration [103-105]. Therefore, further investigation of the antitumor effects of whole-herb preparations and multi-herb formulations is needed.

These compound prescriptions are typically made up of multiple Chinese herbal medicines and are characterized by complex compositions, diverse preparation methods, varying dosages, and distinct therapeutic effects. To unravel the mechanisms of action of these formulations, modern network pharmacology offers a powerful tool. This approach enables the systematic screening of herbal components within a compound and the simultaneous identification of their common molecular targets [106,107]. Furthermore, by analyzing disease-related targets through various databases, researchers can pinpoint the shared targets between the herbal compound and the disease, which may hold the key to effective treatment strategies. This methodology is equally applicable to studying the interaction between *A. tanguticus* and tumors, potentially uncovering targeted therapeutic options for cancer treatment.

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Challenges in Elucidating the Molecular Mechanisms of Major Constituents

Currently, research on the antitumor properties of the active components of *A. tanguticus* is limited. Understanding mechanisms of the components presents a challenge for the clinical translation of these compounds. To address this issue, chemical proteomics techniques, such as affinity selection-mass spectrometry, drug affinity responsive target stability [108], and thermal proteome profiling [109], along with protein small molecule cocrystallization methods, can help identify the targets of small-molecule compounds. This approach can elucidate the molecular mechanisms of action of these compounds against tumors, establish a foundation for clinical applications, and facilitate the transition of antitumor compounds into clinical settings. Ultimately, it aims to improve cancer treatment and mitigate the issue of drug resistance in tumors.

Challenges in Clinical Translation

The current research on the antitumor effects of *A. tanguticus* is predominantly limited to preclinical studies. The formulations and active monomer compounds derived from *A. tanguticus* face several challenges in their clinical application for tumor treatment. These formulations and compounds are primarily known for their anti-inflammatory and analgesic properties. Their antitumor effects largely involve mitigating the inflammatory and painful symptoms associated with tumors, necessitating their use in combination with other targeted antitumor drugs to achieve effective tumor growth inhibition. However, research on the synergistic effects of *A. tanguticus* compounds with targeted antitumor therapies is notably lacking. To bridge this gap, it is crucial to explore combinations of the various active ingredients of *A. tanguticus* with first-line clinical cancer drugs, aiming to identify and optimize the most effective antitumor combination regimens.

Furthermore, the clinical application of these drugs requires rigorous experimental validation and comprehensive safety assessments, which often exceed the financial capabilities of most medical institutions and research units. As a result, due to economic constraints, most research efforts remain focused on basic research, falling short of achieving meaningful clinical translation. To alleviate this financial burden, one promising approach is to investigate the repurposing of existing drugs. For instance, studies could focus on evaluating the antitumor potential of clinically available atropine and anisodamine, leveraging their established safety profiles and known pharmacological properties to accelerate translational research.

Conclusions

Despite the preliminary antitumor potential exhibited by the active components of *A. tanguticus* in preclinical studies, many challenges remain in translating these findings into clinical applications. To overcome these limitations, advanced technologies such as ultrasound-assisted extraction, chemical proteomics (including surface plasmon resonance, activity based protein profiling, and drug affinity responsive target stability), and the repurposing of existing drugs have been developed. Overall, available findings support further preclinical investigation of *A. tanguticus* and its constituents, but no controlled clinical evidence currently supports their use as an anticancer treatment.

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Declaration of Figures' Authenticity

All figures submitted have been created by the authors who confirm that the images are original with no duplication and have not been previously published in whole or in part.

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