Clinical Aspects of Aconitum Preparations*

Abstract

Aconite species have played an important role in human history. Aconitum species have been used worldwide as poisons as well as remedies. Their potential in targeting several ailments such as pain, rheumatism, and lethargy has been recognized by Western, Chinese, and Indian health care practitioners. Aconite use in herbal preparations has declined, especially in Europe and the United States, in the first half of the twentieth century due to several reported toxicity cases. The situation has changed with the application of new technologies for the accurate analysis of its toxic components and the development of efficient detoxification protocols. Some Asian countries started small clinical trials to evaluate the potency and safety of different marketed aconite preparations. The current review summarizes therapeutic uses of aconite preparations in China, Taiwan, India, and Japan. It also highlights clinical trial results with special emphasis on their limitations. Modern drugs and pharmacopeial preparations derived from aconite are also discussed.

Introduction

Aconitum, also known as monkshood, wolf’s bane, or devil’s helmet, has been widely used in folk medicine in China, India, and certain parts of Europe [1–4]. The genus Aconitum (Ranunculaceae) comprises 300 species distributed all over the world [5]. The most common species are Aconitum carmichaelii Deb. and Aconitum kusnezoffii Rchb. in China, Aconitum japonicum Thunb. in Japan, Aconitum napellus L. in Europe, Aconitum ferox Wall. ex Ser. in India, and Aconitum noveboracense A. Gray ex Coville in the United States [5]. Several classes of secondary metabolites, especially alkaloids, have been isolated from different Aconitum sp. [6]. The type of the isolated major alkaloids may vary depending on the species such as aconitine, hyaconitine, and mesaconitine from A. carmichaelii, aconitine from A. napellus, hyaconitine from A. septentrionale Koelle, mesaconitine from A. kusnezoffii, bikhaconitine from A. ferox, talatisamine from A. kongboense Lauener, atisine from A. anthora L., and A. heterophyllum Wall. ex Royle, and lycocoitine from A. vulparia Rchb. [6]. Several isoquinoline alkaloids and phenethylamine derivatives have also been isolated, such as higenamine from A. japonicum, magnoflorine from A. vulparia and A. napellus, corynine from A. carmichaelii, and N-methyl adrenaline from A. nasutum Fisch. ex Rchb. [6]. Lipo-alkaloids including lipoaconitines, lipomesaconitines, lipodeoxyaconitines, and lipohypaconitines were also isolated [7,8].

The efficacy of Aconitum sp. in resolving critical clinical conditions has been proven by doctors practicing traditional Chinese medicine (TCM) and Ayurvedic medicine for centuries. However, the long history of Aconitum sp. misuse in homicide cases has shaken the faith in the potential safe application of this herb in therapy [9,10]. The recent developments in analytical techniques which can identify and determine the concentrations of toxic compounds in herbal products with impressive accuracy and reliability have rekindled the interest in Aconitum preparations [1,5,6,11,12]. A plethora of studies have focused on developing accurate, feasible, and fast analytical techniques to determine the alkaloidal content in each acon-

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* Dedicated to Professor Dr. Dr. h.c. mult. Adolf Nahrstedt on the occasion of his 75th birthday.

# These authors contributed equally to this work.
Table 1  Famous formulas with Fuzi.

<table>
<thead>
<tr>
<th>Formula</th>
<th>Ingredients</th>
<th>Fuzi dosage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sini Tang</td>
<td>Aconitum carmichaeli (Raw Fuzi), Zingiber officinale (Ganjiang), and Glycyrrhiza uralensis (roasted Gancao, licorice)</td>
<td>1 piece (15–30 g)</td>
</tr>
<tr>
<td>Bai Tong Tang</td>
<td>Allium sativum L. (white stem of shallot), Zingiber officinale (Ganjiang), and Aconitum carmichaeli (Raw Fuzi)</td>
<td>1 piece (15–20 g)</td>
</tr>
<tr>
<td>Fuzi Lizhong Tang</td>
<td>Aconitum carmichaeli (Processed Fuzi), Panax ginseng (ginseng), Zingiber officinale (Ganjiang), Atractylodes macrocephala Koidz. (Bai Zhu), Glycyrrhiza uralensis (roasted Gancao, licorice)</td>
<td>1 piece (15–20 g)</td>
</tr>
<tr>
<td>Ma Huang Fuzi Hsi Hsin Tang</td>
<td>Ephedra sinica (Ma Huang), Aconitum carmichaeli (Processed Fuzi), and Asarum sieboldii (His Hsin)</td>
<td>1 piece (15–20 g)</td>
</tr>
<tr>
<td>Jen Wu Tang</td>
<td>Poria cocos F. A. Wolf. (Fu Ling), Panax notoginseng Pallas. (Shaoyao, Chinese peony), Zingiber officinale (fresh ginger), Atractylodes macrocephala Koidz. (Bai Zhu), and Aconitum carmichaeli (Processed Fuzi)</td>
<td>1 piece (15–20 g)</td>
</tr>
<tr>
<td>Fuzi Tang</td>
<td>Aconitum carmichaeli (Processed Fuzi), Poria cocos F. A. Wolf. (Fu Ling), Panax ginseng (ginseng), Atractylodes macrocephala Koidz. (Bai Zhu), and Panax notoginseng Pallas. (Shaoyao, Chinese peony)</td>
<td>2 pieces (30–40 g)</td>
</tr>
<tr>
<td>Ma Huang Fuzi Gancao Tang</td>
<td>Ephedra sinica (Ma Huang), Aconitum carmichaeli (Processed Fuzi), Glycyrrhiza uralensis (roasted Gancao, licorice)</td>
<td>1 piece (15–20 g)</td>
</tr>
<tr>
<td>Gui Zhi plus Fuzi Tang</td>
<td>Ramulus Cinnamomi, Cinnamomum cassia (Gui Zhi), Panax notoginseng Pallas. (Shaoyao, Chinese peony), Glycyrrhiza uralensis (roasted Gancao, licorice), Zingiber officinale (fresh ginger), Ziziphus jujuba Mill. (jujube), Aconitum carmichaeli (Processed Fuzi)</td>
<td>1 piece (15–20 g)</td>
</tr>
</tbody>
</table>

Traditional Chinese Medicine

Aconitum was first introduced in Shennong Ben Cao Jing, which is the earliest Chinese herbs book and might be written around the era of Qin to Western Han Dynasties (221–200 BC) [24, 25]. Aconitum preparations, including Fuzi (aconiti radix lateralis praeparata), Wu Tou (chuan wu, aconiti radix praeparata), and Caowu (A. kusnezoffii), have been recommended for cold limbs, painful knees, walking difficulties, chronic wounds, poor circulation, spasms, and different tumors [3].

The applications of Aconitum were advocated in Shang Han Lun, which was written by Zhang Zhongjing, one of the most respected TCM physicians in history. He lived in the Eastern Han Dynasty around 150–209 AD [26]. He introduced some formulas (Table 1) [26] targeting critical health problems using Fuzi as the main therapeutic agent. In addition to the indications summarized in Shang Han Lun, Fuzi was mainly used to treat patients with general weakness, fatigue, drowsiness, cold extremities, abdominal pain, bone pain, and weak pulse. It was believed that Fuzi was highly effective in improving body circulation [5, 27–29].

Aconitum toxicity remained a major concern to TCM practitioners, and many prominent physicians in the Ming to Qing Dynasties were afraid to use Fuzi in herbal formulas [5]. This cautious trend continued until the renaissance TCM theory in the Han to Tang Dynasties. The physicians living in this period found out that following therapeutic theories introduced by Zhang Zhongjing resulted in impressive results. Spreading this knowledge to the rest of the world started in the nineteenth century with the surge of migration waves from China to Western countries [30]. Many TCM practitioners found that Aconitum played an important role in the history of Western civilization as a lethal herb and as a medication. Through combining knowledge accumulated over centuries from Eastern and Western civilizations, TCM practitioners started to advocate the use of Aconitum against several ailments. Hai-Ha Ni (1954–2012) in the USA, Buto Chang (1942–2012) in Taiwan, Chin-An Zheng (1824–1911) in China, and other prominent TCM physicians introduced different therapeutic regimens containing Fuzi. Aconitum was prescribed for its cardiotonic, antiarrhythmic, analgesic, anti-epileptic, anticancer and antimicrobial activities [3]. In order to maximize the clinical effects, some followers of Chin-An Zheng recommended the use of raw or processed Fuzi in a dose as high as 60–120 g, which was 4–8 times the dosage recommended by previous practitioners. However, the pros and cons of high doses of Fuzi were not investigated.

Practitioners have differentiated in their recommendations between raw and processed Fuzi. In general, raw Fuzi was administrated in more critical conditions, while the processed preparation was used to increase circulation and energy [5]. Recent scientific studies showed that the toxicity of raw Fuzi is reduced by processing due to the hydrolysis of the ester group of the diesterepenoidal alkaloids (aconitine, mesaconitine, and hypoaconitine) (Fig. 1) [4]. Initially, the acetyl group is hydrolyzed and in the second step, the benzoyl group is hydrolyzed (Fig. 2) [17]. This process results in an increase in the concentrations of mono-ester-diterpenoidal alkaloids (benzoylconic, benzoylmesaconine, and benzoylpyaconine) in the processed Fuzi [18]. Also, the concentration of lipox-alkaloids, which are esters of alkaloids with fatty acids in the C-8 position, significantly increased after processing (Fig. 3) [8]. However, there is no detailed clinical study showing the differences in pharmacological activity and toxicity between raw and processed Fuzi. Therefore, it is important to conduct such studies on a reasonable scale to demonstrate the potential and limitations of raw and processed Fuzi. One of the important steps to tackle this problem is the ongoing randomized control trial to evaluate the efficacy of Sini Tang, which uses raw Fuzi, in patients with septic shock [31]. It is hoped that such trials will provide health care authorities with essential in-
formation to establish the necessary measures and regulations of Aconitum use.

Current Herbal Formulas in China

In China, many scientists, physicians, and pharmaceutical companies work together to create new Aconitum-based formulas. Many different hospitals create their own formulas and they also try to formulate Fuzi into pills, capsules, and injections instead of traditional decoctions [28, 29]. The clinical results of different Aconitum formulas reported in English are summarized below.

Qili-qiangxin capsules

The qili-qiangxin capsule was developed and approved in 2004 by the Chinese Food and Drug Administration for the treatment of heart failure [32]. Its development was based on the theory of TCM. The formula contains 11 distinct herbs, in which astragali radix and aconiti lateralis radix preparata (Fuzi) are the principal pharmacologically active components.

One thousand capsules were prepared from ginseng radix et rhizoma (225 g), astragali radix (450 g), aconiti lateralis radix preparata (112.5 g), semen descurainiae lepidii (150 g), Salvia miltiorrhiza Bunge (Lamiaceae) radix et rhizome (225 g), alismatis rhizoma (225 g), ramulus cinnamomi (90 g), polygonati odorati rhizoma (75 g), periplocae cortex (150 g), carthami flos (90 g), and citri reticulatae pericarpium (75 g) [33]. Each capsule was 0.3 g, and patients were advised to take four capsules each time three times a day.

The clinical efficacy of qili-qiangxin capsules in treating heart failure was proved after the publication of a double-blind, multi-center, placebo-controlled, prospective, randomized clinical trial in 435 patients with chronic heart failure in 2013 [34]. Patients included in the trial were diagnosed with heart failure and were found to belong to class II–IV according to the New York Heart Association (NYHA) functional classification. They suffered from a left ventricular ejection fraction (LVEF) ≤40% and a serum NT-proBNP (N-terminal pro-B-type natriuretic peptide) level ≥450 pg/mL. The possible causes of heart failure were cardiomyopathy (56.82%), ischemic heart disease (32.59%), or hypertension (19.75%). In addition, 15.48% of the patients had a medical history of atrial fibrillation and 16.7% had diabetes mellitus.

The results showed that the qili-qiangxin capsule group demonstrated improved symptoms compared to the placebo group after 12 weeks of follow-up. Patients in the qili-qiangxin capsule group (47.95%) showed a reduction in plasma NT-proBNP compared with 31.98% of the patients in the placebo group. Treatment with qili-qiangxin capsules also resulted in superior performance in comparison to the placebo group with respect to NYHA functional classification, LVEF, 6-min walking distance, and quality of life. The detailed mechanism of the qili-qiangxin capsule in treating heart failure is not well established yet. An animal study showed that the qili-qiangxin capsule could downregulate the ratio of tumor necrosis factor-α/interleukin-10 and improve cardiac function in mice with myocardial infarction [35]. It also inhibited myocardial inflammation and the death of cardiomyocytes. On the other hand, it promoted cardiomyocyte proliferation, leading to improved cardiac remodeling and cardiac function [36]. Another study showed that qili-qiangxin improved both systolic and diastolic cardiac functions, and it downregulated the cardiac chymase signaling pathway and chymase-mediated angiotensin II production in hypertensive rats [37]. The other cardioprotective effects of qili-qiangxin were related to the regulation of the glycolipid substrate metabolism by activating AMPK (AMP-activated protein kinase)/PGC-1α (peroxisome proliferators-activ-
vated receptor-γ coactivator-1α) axis. Also, it was suggested that qili-qiangxin reduced the accumulation of free fatty acids and lactic acid protecting cardiac myocytes and mitochondrial function [38].

Regarding the electrophysiological aspects of qili-qiangxin, it was found that the capsule blocks I_{Ca-L} (L-type Ca^{2+} channel) and reduces Ca^{2+} overload. These effects can improve the heart rate similar to the effect of antiarrhythmic agents and improve the overall condition of the heart [39]. Qili-qiangxin was also found to decrease the sodium current (I_{Na}), transient outward K+ current (I_{to}), and activate the delayed rectifier outward K+ current (I_{Ks}) on cardiac ventricular myocytes [40]. These results suggested the potential application of qili-qiangxin capsules as a treatment for heart failure and arrhythmia.

Shenfu injection
Shenfu injection (SFI) is one of the modern formulations of Chinese medicine, which is prepared from red ginseng [steamed roots of Panax ginseng C.A.Mey. (Araliaceae)] and aconite (processed lateral roots of A. carmichaelii) by using countercurrent extraction and macroporous resin adsorption chromatography [41]. A total of 44 components were identified by the high-performance liquid chromatography coupled with quadrupole time-of-flight mass spectrometry (HPLC-QTOF MS) method [41]. An LC-MS method with selected ion monitoring was used to quantify 24 major alkaloids and ginsenosides. The total content of ginsenosides was found to be 676–742 µg/mL, while the alkaloids were present in trace amounts (3–7 µg/mL). In the SFI sample, ginsenosides Rb1 Rg1, and Re were the predominant components, followed by Rc, Rf, and Rb2.

Its clinical application was evaluated against a myriad of ailments including heart failure, septic shock, intradialytic hypotension, post-resuscitation care, cancer, and neuroprotection. A systematic review and meta-analysis study were conducted to evaluate the efficacy of SFI for the treatment of heart failure [42]. The mortality rate in patients with myocardial infarction-induced heart failure was significantly decreased in the shenfu injection (SFI) group. However, the mortality rates in patients with heart failure that was not caused by myocardial infarction was not affected by SFI. On the other hand, the cardiac function in the SFI group was improved according to NYHA classification, not only in myocardial infarction-induced heart failure but also in non-myocardial infarction-induced heart failure. The results of echocardiography also showed that SFI combined with routine treatment such as beta-blockers, ACEI, antihypertensive agents, and diuretics improved left ventricular ejection fraction (LVEF), cardiac output, stroke volume, and the cardiac index (CI) in heart failure patients. SFI also improved the E/A ratio [the ratio of the early (E) to late (A) ventricular filling velocities]. In a healthy heart, the E velocity is greater than the A velocity. In certain pathologies and with aging, the left ventricular wall can become stiff, increasing the back pressure as it fills, which slows the E filling velocity, thus lowering the E/A ratio [43]. The reversal of the E/A ratio (A velocity becomes greater than E velocity) is often accepted as a clinical marker of diastolic dysfunction, suggesting that diastolic function was improved in the SFI group. In the evaluation of biological parameters, SFI significantly reduced NT-proBNP levels and increased the distance of 6-min walking. However, there was no significant difference in blood pressure between the SFI and routine treatment groups.

In the treatment of intradialytic hypotension (IDH), SFI also showed a beneficial effect in hemodialytic patients. Eight randomized, controlled clinical trials were performed with 348 participants during 7974 hemodialysis sessions to evaluate the effect of SFI [44]. The results showed that SFI significantly increased systolic blood pressure but not diastolic blood pressure. The SFI group also showed an improved clinical effective rate compared with the control group. SFI reduced the incidence of hypotension when used to prevent or to treat an episode of intradialytic hypotension (IDH). The albumin level was increased but the C-reactive protein (CRP) level was decreased in patients treated with SFI. No significant side effects were reported. For the management of septic shock, one Chinese systemic review, which included 499 patients in six randomized, controlled trials, concluded that SFI could increase systolic and diastolic blood pressure [45]. It also improved shock symptoms and reduced the heart rate.

Other studies tried to evaluate the effect of SFI in improving the quality of life as well as in treating cancer-related fatigue and anemia [46, 47]. However, the presented results were insignificant. In general, well-organized, controlled clinical trials should be conducted to evaluate the previously reported Shenfu animal studies. These reports indicated that Shenfu acted as a coronary dilator [48] as well as a neuroprotective agent after cardiac arrest [49], post-resuscitation care [50], acute pancreatitis [51], and hypoxic-ischemic brain injury [52]. In addition to qili-qiangxin capsules and SFI, many hospitals are trying to develop other kinds of Fuzi-related formulations with special emphasis on its cardiotonic effect. It is recommended that clinical trials should be conducted in different countries and not only restricted to China to fully exploit the benefits of Aconitum preparations.

Aconitum in Ayurvedic Medicine

Ayurvedic medicine is the Indian traditional medicinal system. Ayurvedic medicine includes the use of herbal, mineral, or metal products as well as surgical techniques and massages. The origin of Ayurvedic medicine is unclear. Some records in Atharvaveda might be written around 1500–1000 BC [53–56]. These records contain 114 hymns and incantations described as magical cures for different diseases, forming the origin of Ayurvedic medicine [53].

Different Aconitum sp. were used by practitioners of Ayurvedic medicine in the preparation of herbal formulas targeting several disorders. However, scientific literature lacks reports on clinical trials evaluating Ayurvedic herbal formulas containing Aconitum. Information on the clinical efficacy of Aconitum preparations comes from the traditional use of this herb over centuries [57, 58]. There are 11 Aconitum sp. used in Ayurvedic medicine. They are used as anti-inflammatory, antiemetic, antirheumatic, and antidiarrheal agents. The details are summarized in Table 2 [57].

Current Applications of Fuzi in Taiwan

In Taiwan, Fuzi is strictly regulated due to its toxicity. According to the Taiwan Herbal Pharmacopeia, the total concentration of diester-diterpenoid alkaloids (aconitine, mesaconitine, and hypaconitine) should not be above 0.020% in crude Fuzi materials. On the other hand, the total concentration of monoester-diterpenoid alkaloids (aconitine, mesaconitine, and hypaconitine) should not be above 0.010% in crude Fuzi materials. According to the Taiwan Herbal Pharmacopeia, the total concentration of diester-diterpenoid alkaloids (aconitine, mesaconitine, and hypaconitine) should not be above 0.020% in crude Fuzi materials. On the other hand, the total concentration of monoester-diterpenoid alkaloids (aconitine, mesaconitine, and hypaconitine) should not be above 0.010% in crude Fuzi materials.
There are not only crude preparations of Fuzi in Taiwan but also commercial products of Fuzi extraction concentrated powder/granules. However, some of the famous Fuzi formulations do not have commercial concentrated TCM powder. After our evaluation, the commercial powder/granule products only include processed Fuzi, Ma Huang Fuzi Hsi Hsin Tang, Fuzi Lizhong Tang, Sini Tanshui, Jen Wu Tang, and Guifu Dihuang Wan (Ba Wei Di Huang Wan).

We examined commercial concentrated Fuzi powder in two GMP commercial products of Fuzi extraction concentrated powder/granule. After our evaluation, the commercial powder/granule products only include processed Fuzi, Ma Huang Fuzi Hsi Hsin Tang, Fuzi Lizhong Tang, Sini Tanshui, Jen Wu Tang, and Guifu Dihuang Wan (Ba Wei Di Huang Wan).

The pharmacokinetics and toxicology of Aconitum preparations were also studied [69, 70]. It was revealed that aconite tuber can regulate peripheral vascular function by increasing the plasma levels of nitrite and nitrate, which was in agreement with the theory of Kampo medicine [71].

Aconite is used in Kampo medicine because of the deep influence by Shanghang Lun. Due to its toxicity, scientists analyzed the alkaloid content, nuclear DNA region, and internal transcribed spacer (ITS) from 107 Aconitum plants in Japan [67] and set the standard analytical method in the Japanese pharmacopeia [68]. The pharmacokinetics and toxicology of Aconitum preparations or powders were also studied [69, 70]. It was revealed that aconite tuber can regulate peripheral vascular function by increasing the plasma levels of nitrite and nitrate, which was in agreement with the theory of Kampo medicine [71].

The analgesic effect of Aconitum chinense species such as Tashiro Sanki (1456–1537), Nagoya Geni (1628–1696), and Yoshimatsu Todo (1702–1773) contributed significantly to its progress. Ishizaka Sotetsu (1770–1841) and Honma Soken (1804–1872) even tried to incorporate Western medicine theory into Kampo medicine [64]. Influenced by Western medicine, Japanese physicians tried to apply Kampo formulas to Western medical diseases. In order to set the standard of its clinical practice, physicians used fixed combinations of herbs in standardized proportions, which may be derived from TCM formulas or Japanese physicians. They fit the indications of these formulas one by one to Western diseases based on clinical evidence. There are more than 148 Kampo formulas approved as prescription drugs, which accounts for 1.34% of the total number of prescriptions in Japan [65]. Physicians in Japan not only prescribe Western medicine but also Kampo medical herbs. According to a nationwide study in 2000, almost 72% of physicians have prescribed Kampo medical herbs [66]. Such an attitude has a great influence on the development of Kampo medicine.

Kampo medicine is a Japanese medical system derived from TCM, which might have passed to Japan during the Tang Dynasty around 700–800 AD [61–63]. Kampo medicine focuses on herbs, acupuncture, and moxibustion. Many classical TCM books such as Huangdi Neijing, Shennong Ben Cao Jing, and Shanghan Lun set the standard of the treatment theory. Since then, Japanese doctors have improved the theory borrowed from TCM according to their clinical experiences and observations. Many famous Japanese doctors such as Tashiro Sanki (1456–1537), Nagoya Geni (1628–1696), and Yoshimatsu Todo (1702–1773) contributed significantly to its progress. Ishizaka Sotetsu (1770–1841) and Honma Soken (1804–1872) even tried to incorporate Western medicine theory into Kampo medicine [64].

Aconite Preparations in Kampo Medicine

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The analgesic effect of Aconitum was also investigated. A case series study showed that 12 postherpetic neuralgia patients showed improvement in a visual analogue pain scale under the treatment combination of Keishikajutsubuto (TJ-18) 7.5 g/day and Bushi-matsu (TJ-3022) 1.0–5.0 g/day [72]. The results of animal studies supported the analgesic effect of Aconitum formulas such as Tsumura-shuuij-bushi-matsu [73] and kako-bushi-matsu [74].
The famous aconite Kampo medicine preparations and their indications are listed in Table 3 [62, 63, 65, 75]. It shows that Aconitum is applied in many different clinical situations. The efficacy of some formulations has been proven by small clinical studies. For example, Goshajinkigan was shown to have a benefit in the treatment of lymphedema [75, 76].

Some Kampo formulations are directly derived from TCM. For example, Hachimijiogan was derived from Ma Huang Fuzi Hsi Hsin Tang. Hachimijiogan, with the same ingredients as Ba Wei Di Huang Wan in TCM, showed a beneficial effect in improving MMSE (Mini-Mental State Examination). It also improved the activities of daily living (ADLs) score in the Barthel Index in severe dementia patients after an eight-week treatment course in a randomized, double-blind, placebo-controlled trial [77].

**Aconitum in Homeopathy**

Homeopathy is a system of alternative medicine created by the German physician Samuel Hahnemann (1755–1843) [78]. Hahnemann advocated the principle that effective drugs produce symptoms in healthy individuals similar to those of the diseases that they treat, like cures like. He used herbal medicines to treat diseases. The first usage of A. napellus in homeopathy was recorded in Materia Medica Pura, which was written by Samuel Hahnemann in 1810. A. napellus was prescribed as an antipyretic and anti-inflammatory agent. It was also recommended to overcome fear, neuralgia, and urinary problems [79]. However, the effectiveness of A. napellus in homeopathy is still controversial. In a randomized, double-blind, controlled crossover study, A. napellus C30 (dilution of 10^60 times) yielded statistically significant results between the classified reactions compared with the placebo in healthy volunteers [80].

One prospective observational study showed similar efficacy of using different homeopathic remedies (A. napellus, Apis mellifica, Belladonna, Capsicum, Chamomilla, Kalium bichromicum, Lachesis, Lycopodium, Mercurius solubilis, Okoubaka, Pulsatilla, Silica, Lycopodium, Mercurius solubilis, Okoubaka, Pulsatilla, Sili-
Table 4  List of drugs containing aconite.

<table>
<thead>
<tr>
<th>Name of the drug/country</th>
<th>Ingredients</th>
<th>Indications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aconit Schmerzer/Austria</td>
<td>Aconite</td>
<td>Homeopathic preparation</td>
</tr>
<tr>
<td>Aconitum Compositum/Germany</td>
<td>Aconite</td>
<td>Homeopathic preparation</td>
</tr>
<tr>
<td>Aconitum Nicotiana comp/Germany</td>
<td>Aconite</td>
<td>Homeopathic preparation</td>
</tr>
<tr>
<td>Aconitum-Homaccord/Austria</td>
<td>Aconite</td>
<td>Homeopathic preparation</td>
</tr>
<tr>
<td>Agrime/Brazil</td>
<td>Aconite, rorippa nasturtium aquaticum, tolu, ipecacuanha</td>
<td>Cough</td>
</tr>
<tr>
<td>Anti-Crine/Dry Cough Relief/Australia</td>
<td>Anise oil, marshmallow, white bryony, Iceland moss, echinacea, chamomile, thyme, urcha, acinet, ammonia, coccus, cactus, corallium rubrum, drosera rotundifolia, ipecacuanha, kall bich, kreosotum, spongia tosta, sticta pulmonaria</td>
<td>Cough</td>
</tr>
<tr>
<td>Calmarum/Portugal</td>
<td>Sulfogaiacol, ephedrine hydrochloride, ethylmorphine (dionina), sodium benzoate, acinet, thyme, and senega</td>
<td>Cough</td>
</tr>
<tr>
<td>Cold &amp; Flu Respationon/ Dry Cough Relief/Australia</td>
<td>Anise oil, althaea, bryonia, Iceland moss, echinacea, chamomile, thyme, urcha, Aconitum nap, coccus, cactus, corallium rubrum, drosera, ipecacuanha, kall bich, kreosotum, spongia tosta, sticta pulmonaria</td>
<td>Cough</td>
</tr>
<tr>
<td>Colimax/Belgium</td>
<td>Ephedrine hydrochloride, sodium benzoate, acinet, belladonna, thyme, wild thyme, maidenhair fern</td>
<td>Cough</td>
</tr>
<tr>
<td>Cough Relief/Australia</td>
<td>Anise oil, althaea, bryonia, Iceland moss, echinacea, chamomile, thyme, urcha, Aconitum nap, coccus, cactus, corallium rubrum, drosera, ipecacuanha, kall bich, kreosotum, spongia tosta, sticta pulmonaria</td>
<td>Cough</td>
</tr>
<tr>
<td>Encilina/Spain</td>
<td>Aconite, arnica, ipecacuanha, chamomile, rhatany, iodine</td>
<td>Mouth inflammation, pneumonia</td>
</tr>
<tr>
<td>Eucalyptine Pholcodine Le Brun/Belgium</td>
<td>Sulfogaiacol, sodium camisilate, sodium phenolsulfonate, pholcodine, belladonna, acinet, cineole</td>
<td>Respiratory disorders</td>
</tr>
<tr>
<td>Expectomel/Brazil</td>
<td>Rorippa nasturtium aquaticum, aconite, ipecacuanha, senega, tolu balsam, honey, guaco</td>
<td>Respiratory tract congestion</td>
</tr>
<tr>
<td>Hachimi-jio-gan/Japan</td>
<td>Rehmannia root, cornus fruit, discoorea rhizome, alisma rhizome, poria sclerotium, moutan bark, cinnamomum, acinet, tolu balsam</td>
<td>Traditional Kampo medicine</td>
</tr>
<tr>
<td>Keishikajutsubuto/Japan</td>
<td>Cinnamom bark, peony root, atractylodes lancea rhizome, jujube, liquorice, ginger, acinet root</td>
<td>Traditional Kampo medicine</td>
</tr>
<tr>
<td>Lactocol/Italy</td>
<td>Guaiacol, lactic acid, calcium phosphate, calcium lactate, codeine hydrochloride, acinet</td>
<td>Cough</td>
</tr>
<tr>
<td>Melagriao/Brazil</td>
<td>Nosturtum officinale, acinet, mikania glomerata, ipecacuanha, senega, tolu balsam, honey</td>
<td>Respiratory tract congestion</td>
</tr>
<tr>
<td>Padma/Switzerland</td>
<td>Aconite, aegle sepiar, ammi fruit, aquilegia, calendula, camphor, cardamom, clve, costus root, hedychii rhizome, lettuce, Iceland moss, liquore, meliae tsaend, myrobalan, ribwort plantain, knotgrass, golden potentiola, sandalwood bark, sidae cordifoliae, valerian, calcium sulfate</td>
<td>Circulatory disorders</td>
</tr>
<tr>
<td>Pectal/Brazil</td>
<td>Sodium dibunate, acinet, cineole, grindella, mikania glomerata, senega</td>
<td>Cough</td>
</tr>
<tr>
<td>Pleumolysin/Czech Republic</td>
<td>Codeine phosphate, thyme, gypsophila saponin, acinet, bitter-orange peel</td>
<td>Coughs, respiratory tract inflammation</td>
</tr>
<tr>
<td>Vifor/Switzerland</td>
<td>Ethylmorphine hydrochloride, sulfogaiacol, sodium benzoate, belladonna, hyssopus officinalis, tolu balsam</td>
<td>Coughs, respiratory tract disorders</td>
</tr>
<tr>
<td>Xarope de Caraguata/Brazil</td>
<td>Annona muricota, bromoform, sodium benzoate, acinet, belladonna, tolu balsam, grindella</td>
<td>Cough</td>
</tr>
</tbody>
</table>

peutic index (LD50/ED50) [90]. Such potent activity encouraged researchers to subject lappaconitine to further studies. Large-scale protocols have been developed for the extraction and purification of this alkaloid from the roots of Aconitum leucostomum Vorosch. and A. septentrionale [91].

Clinical studies started in the 1980s, focusing on the effect of lappaconitine on the hemodynamics and myocardial contractility of patients with heart rhythm disorders [92]. The drug proved to be effective as class 1C antiarrhythmic drugs. It was more effective than ethmozine and ethacizine in preventing ventricular and supraventricular extrasystoles. This effect was demonstrated in a clinical trial with patients suffering from arrhythmias of different etiology [93]. In paroxysmal ventricular tachycardia, lappaconitine hydrobromide had a similar efficacy to ethacizine and bonnecor [94], even in the case of long-term treatment [95]. In paroxysmal supraventricular arrhythmia, it exerted similar preventive antiarrhythmic efficacy to the class 1 antiarrhythmic drugs tachmalcor and propafenone [96]. According to a review on clinical trials, lappaconitine hydrobromide is especially effective in the prevention of paroxysmal atrial fibrillations [97]. A recently published study reported its efficacy in preventing ventricular premature beats [98]. Alapimini, similar to class IC antiarrhythmic drugs, causes a prolonged blockade of cardiomycocytes Na+ channels; however, contrary to other drugs such as lidocaine, it acts reversibly only on open channels. Moreover, recent studies revealed that lappaconitine hydrobromide decreased mRNA levels...
for the gene coding of certain K+- and Na+-channels and membrane transporter genes [99]. Alternatively, acetylcholine (former name Guanfu base A), a diterpene alkaloid isolated from Aconitum koreanum R. Raymond, has been approved for the treatment of paroxysmal supraventricular tachycardia in 2005 in China [100]. In a study, patients with sustained supraventricular tachycardia using intravenous acetylcholine showed comparable results to the group under propafenone [101]. In a further study, the intravenous administration of aconitine hydrochloride showed comparable results to the group with sustained supraventricular tachycardia using intravenous acehytisine potassium. However, it does not induce QT interval prolongation [100]. These two alkaloids are currently used in the market due to their favorable benefit-risk ratio compared to other, conventional antiarrhythmic drugs.

Toxicity of Aconite Preparations

The toxicity of Aconitum is notorious, as mentioned in all ancient records. Shakespeare highlighted the potency of this herb in his novel Romeo and Juliet, in which he stated that Romeo committed suicide using this poison [103]. Also, in Macbeth, the witches’ brew calling for “tooth of wolf” refers to monkshood. Certain species are known also as wolfsbane because arrows dipped in the poison kill wolves. The emperor Trajan (98–117 AD) banned the growing of this plant in all Roman domestic gardens [104]. One of the most remarkable pieces, which described the role played by this plant in ancient Roman society, was summarized by the writer Ovid [104]. He referred to aconite as the “step-mother’s poison.” In the first Potions class in Hogwarts, Prof. Severus Snape informed Harry Potter about the toxicity of wolfsbane, which is the main ingredient of Wolfsbane Potion [105].

In recent years, many cases of Aconitum poisoning were published worldwide. Cases were concentrated in the Far East, with few cases in India or Europe. Until 2006, there were over 600 reported cases of Aconitum poisoning in China [106]. In Taiwan, 17 cases were reported from 1990 to 1999 [107]. In Hong Kong, the incidence of aconite poisoning was estimated to be 0.60 per 100000 populations from 1989 to 1993. But the annual incidence of herb-induced aconitine poisoning in the New Territories East in Hong Kong significantly decreased to 0.17 per 100000 populations after the publicity measures from 1996 to 1998 [108].

In general, Aconitum poisoning results from the direct oral intake of Aconitum decoctions or pills. Toxicity through dermal penetration is rare and only 14 cases of poisoning have been reported following the topical application of aconite preparations until 2011 [109]. In the two fatal cases, the epidermis and dermis at the sites of application were already damaged as a result of hot water scalding or herpes zoster infection. Both of the victims applied self-prepared aconite tincture, and one of them used raw “caowu (A. kusnezoffii)” 8 g and raw “chuanwu” 8 g in the application, which is even considered an overdose under normal circumstances. It was also suggested that the absence of an intact epidermis (stratum corneum) due to injury or diseases might significantly increase the systemic absorption of Aconitum alkaloids. To improve the safety of topical Aconitum preparations, alkaloid content is maintained as low as possible (0.119 mg per plaster) by manufacturers, but their use should be under medical supervision [110].

A study reported four “hidden” Aconitum poisoning cases, which did not include aconite in their prescriptions. Aconitum involvement was suspected due to the similarity of poisoning symptoms. Moreover, yunaconitine, which is not one of the common toxins (aconitine, hypaconitine, and mesaconitine), was also speculated to be involved in aconite toxicity [111]. Although it is uncommon, this may be just the tip of an iceberg with some cases going unrecognized.

The clinical presentation of Aconitum poisoning varies depending on the situation. From the experience of TCM doctors, the first symptom of Aconitum poisoning might be numbness of the tongue and lips. Other common symptoms are as follows: paresthesia and numbness over the face and limbs, nausea, dizziness, vomiting, abdominal pain, cold sweating, palpitations, bradycardia, tachycardia, hyperventilation, chest tightness, and hypotension. The mean latent period is 43.6 min [107], but it may differ depending on the dosage. Electrocardiography in these patients may show ventricular tachycardia, ventricular fibrillation, premature ventricular contractions, multifocal ventricular ectopics, sinus tachycardia, and bradycardia [107–109, 112]. There is no specific dose-response relationship in these studies. Furthermore, it may elevate troponin-I and creatine kinase (CK), which mimics acute myocardial infarction [113].

The treatment of Aconitum poisoning depends on supportive care, some physicians tried MgSO4, lidocaine, atropine, current shock, and a temporary pacemaker to correct patients’ heart rhythm [107, 112]. The toxicokinetic information is not well established in aconite poisoning. One study showed that the aconitine half-life is 3.7–17.8 h, its AUC is 2.4–5.1 ng × h/mL, and its mean residence time is 10.8–23.6 h. Mesaconitine half-life is 2.8–5.8 h, its AUC is 5.4–13.0 ng × h/mL, and its mean residence time is 9.7–11.9 h. Jesaconitine half-life is 5.8–15.4 h, its AUC is 6.9–33.5 ng × h/mL, and its mean residence time is 11.5–22.6 h. The range is wide because of the influence of liver and kidney function in herbal detoxification [112]. After appropriate treatment, most patients can recover without a specific sequela within eight days [107].

According to these studies, it is generally understood that the usage of Aconitum sp. should be under clinical supervision to prevent toxicity. More clinical trials should be conducted to reveal the optimum dosage, processing method, and formulations.

Detoxification Protocols

In ancient times, TCM practitioners tested several methods to reduce the toxicity of raw Fuzi. Some healers increased the decoction time, which led to a significant reduction in toxicity. Others mixed the herb with radix glycyrrhizae, P. ginseng, or Zingiber officinale Roscoe (Zingiberaceae) to decrease the toxicity of Fuzi and enhance its efficacy [114]. For example, Sini Tang is formed of radix glycyrrhizae (Gancao) and Z. officinale (Ganjiang) in combination with raw Fuzi. The effect of this preparation was attributed to the interaction between glycyrrhizin, liquoritin, and Fuzi alkaloids [115]. Furthermore, additional processing methods were developed over the years, including soaking in water, stirring, boiling, roasting, and steaming [116].

Some excipients were added during processing, including salts, green beans, licorice, and ginger, to reduce toxicity and improve efficacy. Yanfuzi, Heishunpian, Baijupian, Danfupian, and Paofupian are common processed products in Asian markets [106] (Table 5). All of the mentioned processing methods helped to
reduce Fuzi toxicity by decomposing DDAs to the less toxic monoester-diterpenoid alkaloids (MDAs) [117]. After processing, the content of the highly toxic DDAs is generally reduced 40- to 70-fold compared to raw Fuzi.

Indian healers used different methods for the detoxification of aconite preparations known as Shodhana. It is based on treating the herb with cow dung, cow urine, or cow milk andsubjecting the treated material to sunlight for a certain period of time using special containers [118]. Kampo practitioners added other nontoxic herbs to aconite roots such as cinnamon and atractylodes (Keishibukuryogan) as well as Ma-huang and asarum (Maobushi-isaihinto) [119]. Asian decedents and Asian communities in other countries followed TCM practitioners detoxifying protocols with minor modifications [120].

The regulations of these toxic products differ among countries. It can only be imported or exported under strict regulations. The total amount of aconitate, hysaconitine, and mesaconitine should be less than 0.020% in aconite products in China and Taiwan [106]. In Japan and Europe, extra restrictions are applied and the concentration of toxic alkaloids (DDAs) is further reduced [121]. The concentrations of the nontoxic alkaloids should not exceed 3%, such as aconitic, malic, quinic, chlorogenic, and caffeic acid. In the USA and Canada, there are no specific regulations on Aconitum preparations, and reported toxic cases were mainly due to misidentification and misuse of the herb [122]. Different analytical techniques were developed to analyze and quantify the concentrations of aconite alkaloids, including HPLC, LC-MS, LC-MS/MS, and electrophoresis, with impressive accuracy and speed [3,17,18].

**Table 5** Common Fuzi detoxification protocols in China.

<table>
<thead>
<tr>
<th>Product name</th>
<th>Processing methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yanfuzi</td>
<td>Soaked with salts (MgCl2 or NaCl) and dried in the sun. The surface of Fuzi is usually covered with salts.</td>
</tr>
<tr>
<td>Heishunpian</td>
<td>Soaked with salts and boiled in water, resulting in the formation of a transparent mass. This mass is sliced and brown sugar with oil is added giving the slices a brown color. Slices are then steamed, roasted, and dried.</td>
</tr>
<tr>
<td>Ballupian</td>
<td>Soaked with salts and boiled in water, leading to the formation of a transparent product. This product is sliced, steamed, and smoked with sulfur, rendering the slices white in color. Slices are then roasted and dried.</td>
</tr>
<tr>
<td>Danfupian</td>
<td>Yanfuzi is cleaned from salt by soaking in water. The product is sliced, boiled with licorice and black beans, and finally dried in the sun.</td>
</tr>
<tr>
<td>Paofupian</td>
<td>Yanfuzi salt is removed by soaking in water. The preparation is then sliced, soaked with ginger juice, roasted, and fried.</td>
</tr>
</tbody>
</table>

**Conclusion**

Aconite has been and will remain a mysterious herb. It is like Janus in Greek mythology with two faces, one supports healing and the other leads to death. Its long history of use did not eliminate suspicion and confusion about its true nature. TCM, Kampo, and Ayurvedic practitioners have studied this herb in depth and introduced a plethora of protocols to reduce its toxicity. Serious clinical trials have just started in China in the last decades aiming to reveal aconite’s true therapeutic potential. These trials suggested that qili-qiangxin capsules and SFI are efficient in treating heart diseases. Homeopathy and Ayurveda therapeutic systems have used aconite for centuries, but without any reported clinical trials. Practitioners of Kampo medicine have performed small trials, which suggested potent aconite analgesic activity. Despite such attempts, the global official aconite usage is still in its infancy. It is recommended to conduct more clinical trials on different populations using available Aconitum sp. The results of these trials will assist health care authorities to regulate and control aconite preparations for the safety and benefits of patients.

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**Conflict of Interest**

The authors declare no conflict of interest.

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