REVIEW ARTICLE

Poisoning by Herbs and Plants: Rapid Toxidromic Classification and Diagnosis

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The American Association of Poison Control Centers has continued to report approximately 50,000 telephone calls or 8% of incoming calls annually related to plant exposures, mostly in children. Although the frequency of plant ingestions in children is related to the presence of popular species in households, adolescents may experiment with hallucinogenic plants; and trekkers and foragers may misidentify poisonous plants as edible. Since plant exposures have continued at a constant rate, the objectives of this review were (1) to review the epidemiology of plant poisonings; and (2) to propose a rapid toxidromic classification system for highly toxic plant ingestions for field use by first responders in comparison to current classification systems. Internet search engines were queried to identify and select peer-reviewed articles on plant poisonings using the key words in order to classify plant poisonings into four specific toxidromes: cardiotoxic, neurotoxic, cytotoxic, and gastrointestinal-hepatotoxic. A simple toxidromic classification system of plant poisonings may permit rapid diagnoses of highly toxic versus less toxic and nontoxic plant ingestions both in households and outdoors; direct earlier management of potentially serious poisonings; and reduce costly inpatient evaluations for inconsequential plant ingestions. The current textbook classification schemes for plant poisonings were complex in comparison to the rapid classification system; and were based on chemical nomenclatures and pharmacological effects, and not on clearly presenting toxidromes. Validation of the rapid toxidromic classification system as compared to existing chemical classification systems for plant poisonings will require future adoption and implementation of the toxidromic system by its intended users.

Key words: poisonous plants, poisonous herbs, intentional poisonings, unintentional poisonings, poisonous ingestions, poisonous foods

Introduction

Although serious plant ingestions are uncommon, the American Association of Poison Control Centers (AAPCC) has continued to report approximately 50,000 telephone calls or 8% of incoming calls annually related to plant exposures, mostly nonlethal plant

ingestions in children.^{1,2} Although the frequency of plant ingestions in children is related to the presence of popular species in households, adolescents may experiment with hallucinogenic plants, and trekkers and foragers may misidentify poisonous plants as edible.^{3–6}

In a study designed to assess the ability of emergency department staff doctors and nurses to correctly identify poisonous plants, Harchelroad et al⁴ reported that only 17% of the plants could be identified by their common names, and only 13% could be identified as poisonous. Because plant exposures have continued at a relatively constant rate and the misidentification of poisonous plants has continued among outdoor enthusiasts and medical providers alike, the objectives of this review were 1) to review the epidemiology of plant poisonings

Financial support: Support was provided by departmental and institutional sources. The author has no financial interests or other acknowledgments to disclose.

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and their outcomes, and 2) to propose a rapid toxidromic classification system for highly toxic plant ingestions in comparison with current classification systems.

Methods

To identify peer-reviewed, published scientific articles on herbal and plant poisonings and to develop a simplified toxidromic classification system for rapid diagnosis and management of plant poisonings for first responders and other urgent healthcare providers, Internet search engines, including PubMed, Medline, Ovid, Google, Google Scholar, and Cochrane, were queried with several key words. The key words included the following terms: plants, herbs, poisonous; poisonings, intentional, unintentional; ingestions, poisonous; foods, poisonous.

Plant poisoning reports were stratified as poisonings by either herbs or plants. Herbs were defined as seed-bearing, flowering plants without year-round woody stems as compared with other plants, shrubs, and trees with perennial woody stems. Case reports, case series, poison control center surveillance system reports, review articles, and toxicological studies were reviewed. Table 1 lists the scientific articles selected for review and stratifies them by their manuscript types.

The inclusion criteria for selected scientific articles included unintentional and intentional plant poisoning cases that were reported as individual cases or case series. The unintentional plant poisoning cases included attempted and successful suicides after plant, herb, and seed ingestions, but did not include any homicidal plant poisoning cases. Other inclusion criteria included periodic analyses of AAPCC Toxic Exposure Surveillance System (TESS) databases and other statewide poison control databases for descriptive epidemiological reviews

Table 1. Poisonous garden and wild plants capable of causing fatal toxicity

Types of scientific articles selected for review*	Number of scientific articles reviewed
Case reports	22
Case series	14
Surveillance studies, including Poison Control Center experiences	7
Reviews	6
Toxicological studies	1
Total articles selected and reviewed	50

* Solicited textbook chapters (n = 5) were used as references in this article, but were not considered peer-reviewed and were not selected as articles to be reviewed.

of plant poisonings during the reporting period, 1983–2012.^{1,2,5–7} Exclusion criteria for plant poisoning cases included any plant poisonings in which the toxic plant or herb was not identified and all textbook chapters that were considered solicited, not peer-reviewed scientific publications. Textbook chapters, however, provided the two different plant poisoning classification schemes for comparison with the proposed rapid toxidromic classification system (Table 2).^{8–10} The well-documented cases of plant and herbal poisonings and the descriptions of their toxidromes were then identified from the selected scientific articles and classified into 4 distinctly different resultant toxidromes: 1) cardiotoxic, 2) neurotoxic, 3) cytotoxic, and 4) gastrointestinal/hepatotoxic.

Results and Discussion

THE EPIDEMIOLOGY AND OUTCOMES OF PLANT POISONINGS

Krenzelok et al^{5,6} have periodically analyzed the AAPCC TESS databases on plant poisonings for more than 20 years. During the decade 1985–1994, these authors analyzed 912,534 plant exposures to determine the most common plant exposures.⁵ Garden and household *Philodendron* species were the most commonly ingested species, followed by *Dieffenbachia* (dumb cane) species, *Euphorbia pulcherrima* (poinsettia), *Capsicum annuum* (red pepper), and *Ilex* (holly) species.⁵ During the decade 2000 to 2009, these authors analyzed 668,111 plant exposures as single-substance exposures with the age of exposed patients known in most (n = 611,708) of the cases.⁶ Male patients accounted for 52.2% of the plant ingestions and more than 60% of the moderate and severe outcomes.⁸ The most severe outcomes occurred in those who intentionally ingested plants for their hallucinogenic effects or to commit suicide.⁶ Children younger than 5 years accounted for 81.2% of the plant exposures.⁶ Within the pediatric exposure category during the decade 2000 to 2009, 57.8% of the plant exposures occurred in children younger than 1 year.⁶ During the 26-year period, 1983 to 2009, there were 45 cases of fatal plant poisonings, with *Datura* species (family Solanaceae) and *Cicuta maculata* (water hemlock) responsible for 35.5% of the fatalities.⁶

In a more recent annual analysis of the AAPCC TESS database in 2012, there were 49,373 plant exposures reported, and plants were the 19th most frequently ingested substances in human exposures, responsible for 1.84% of all substance exposures and 2.30% of single-substance exposures.² Plants were the ninth most frequently ingested foreign substance in children 5 years and younger, responsible for 2.78% of all substance

Table 2. A Comparison of the proposed and existing classification systems for plant poisonings

Classification systems	Proposed new classification	Goldfrank et al classification ¹⁰	Nelson et al classification ⁸
Classification methods	Classification by toxidromes	Classification by “pharmacognosy”	Classification by chemical compounds
Classification categories	Cardiotoxic	Alkaloids	Anticholinergics (antimuscarinics)
	Neurotoxic	Glycosides	Calcium oxalate crystals
	Cytotoxic	Terpenes and resins	Cardioactive steroids and glycosides
	Gastrointestinal/hepatotoxic	Proteins, peptides, and lectins Phenols and phenylpropanoids	Cyanogenic compounds Gastrointestinal poisons Mitotic inhibitors Nicotinlike alkaloids Pyrrolizidine alkaloids Sodium channel activators Toxalbumins

exposures and 2.87% of single-substance exposures.² When stratified by plant types among all age groups, the top 3 categories responsible for 12.2% of all plant exposures in 2012 were by unknown, unspecified, or unidentified plants.² When positive plant identifications were made and reported in 2012, the top 6 most frequently confirmed plant exposures in descending order were to *Phytolacca americanum* (pokeweed or pokeberry), *Spathiphyllum* (peace lily) species, *Ilex* (holly) species, *Philodendron* species, *Malus* (apple and crabapple) species, and cardiac glycoside-containing plants, such as foxglove and oleander.²

Several descriptive analyses of passive toxic exposure surveillance system data during the AAPCC reporting period 1983–2012 have confirmed that plant exposures are decreasing with time, but remain common and are rarely serious or fatal. Most plant exposures occurred in men and in children younger than 5 years, with a significant number of indoor exposures in children younger than 1 year. The most commonly ingested plants were popular indoor plants including *Philodendron* and many of the decorative holiday species, such as *Ilex* (holly) and *Euphorbia* (poinsettia). Fatal plant ingestions occurred most often in adolescents and adults intent on self-harm or hallucinogenic plant abuse.

A TOXIDROMIC CLASSIFICATION SYSTEM FOR RAPID DIAGNOSIS OF PLANT POISONINGS

As noted, significant confusion in properly identifying toxic vs nontoxic plants was initially reported by Harchelroad et al⁴ in a study among emergency

department staff who failed to identify poisonous plants most of the time (87%). Confusion in correctly identifying toxic plants continued in later descriptive analyses of AAPCC TESS data when the most common plant exposures were to “unknown, unspecified, or unidentified plants” in 12.2% of reported cases.² As a result, a toxidromic classification of plant poisonings was developed for use by first-responders and other urgent healthcare providers to assist in rapid identification of poisonous plant-induced toxidromes and to reduce confusion among highly toxic, less toxic, and nontoxic plants. The resultant 4 specific toxidromes of plant poisonings identified in the scientific literature could be stratified as cardiotoxic, neurotoxic, cytotoxic, and gastrointestinal/hepatotoxic poisonings, all of which have caused fatalities worldwide after both intentional and unintentional ingestions.

Table 2 compares the proposed rapid toxidromic classification system for plant poisonings with other presently used classification schemes. The current textbook classification schemes for plant poisonings were more complex, more confusing, and more cumbersome than the rapid classification system and were based on either plant chemicals or their pharmacological effects, not on plant-induced toxidromes.^{8–10} The resultant 4 toxic plant ingestion toxidromes were defined as follows.

The cardiotoxic toxidrome was a constellation of digitalis toxicity–like symptoms and signs including nausea, vomiting, bradycardia, hyperkalemia, atrioventricular conduction blocks, and ventricular arrhythmias.

The neurotoxic toxidrome was a constellation of neurological symptoms and signs ranging from

predominantly anticholinergic manifestations (mydriasis, facial flushing, dry skin, tachycardia, mental status changes, combative behavior, hallucinations) to nicotinic and neuromuscular manifestations (ataxia, tachycardia, hypertension, seizures, weakness, paralysis, respiratory failure).

The cytotoxic toxidrome was a constellation of abdominal pain, nausea, vomiting, watery-to-bloody diarrhea, weakness, dehydration, hypotension, metabolic acidosis, elevated serum creatinine, and multiorgan failure.

The gastrointestinal/hepatotoxic toxidrome was a constellation of manifestations ranging from upper gastrointestinal signs of drooling and dysphagia to abdominal pain with increasing hepatic enzyme levels and later jaundice.

These 4 toxidromes were further described by their mechanisms of toxicity and by examples of representative, causative species in Table 3.

EVIDENCE IN SUPPORT OF THE FOUR RESULTANT POISONOUS PLANT TOXIDROMES

Cardiotoxic poisonings

The cardiotoxic plants have been mistaken for edible herbs (dandelions) and bulbs (wild onions) or intentionally ingested in suicide attempts (foxglove, Japanese yew, and oleander) and include the cardiac glycosides, sodium channel activators, and dual sodium and calcium channel blockers. Poisonings after ingestions of plants containing cardiac glycosides resemble digitalis toxicity with initial nausea, vomiting, and abdominal pain, followed by bradycardia with predisposition to hyperkalemia, atrioventricular conduction blocks, and ventricular tachyarrhythmias.^{9–19}

In a 2010 review, Bandara et al¹¹ noted that poisonings with both common oleander (*Nerium oleander*) and yellow oleander (*Thevetia peruviana*) were frequent causes of toxicological emergencies throughout the tropical and subtropical world, with yellow oleander often ingested in suicide attempts throughout Southeast Asia, especially in India and Sri Lanka (Figure 1). The ingestion of either oleander species resulted in nausea, vomiting, abdominal pain, diarrhea, cardiac dysrhythmias, and hyperkalemia.¹¹ The authors also noted that although digoxin-specific Fab antibody fragments were effective, but expensive, antidotes for oleander poisonings, the limited economic resources in most Southeast Asian countries restricted Fab fragment use.¹¹ Most oleander poisoning cases in Southeast Asia were managed with oral activated charcoal administration and supportive care.^{11,12}

Although specifically designed for the management of digoxin toxicity, digoxin-specific Fab antibodies possess sufficient immunological cross-recognition capabilities to bind the cardiac glycoside antigens from several cardiotoxic plants, including *Convallaria majalis* (lily of the valley), *Digitalis* (foxglove) species, *N oleander* (common oleander), *T peruviana* (yellow oleander), and *Ornithogalum umbellatum* (star of Bethlehem) (Table 3).^{9,10} Fab fragments are indicated in empiric intravenous doses (10–20 vials of 30–40 mg each) in cardiac glycoside plant poisoning cases with refractory bradycardia, hyperkalemia, and ventricular tachydysrhythmias, with or without elevated serum digoxin levels.¹⁰

Although poisonings with cardiotoxic plants containing sodium channel openers, such as monkshood (*Aconitum* spp) and death camas (*Zigadenus* spp) mimic cardiac glycoside poisoning on initial presentation with bradycardia, heart blocks, and ventricular tachydysrhythmias, sodium channel activator poisonings are often accompanied by hypotension and cardiovascular collapse.^{13–15} In addition, they are refractory to reversal with digoxin-specific Fab fragments, and may require intravenous atropine and sodium bicarbonate infusions, inotropic support, temporary cardiac pacing, and temporary extracorporeal life support with cardiopulmonary bypass (Figure 2).^{13–15}

In 2011, Dwivedi et al¹⁶ in Delhi, India, reported 12 poisoning cases with 3 deaths after the ingestion of herbal therapy preparations containing a variety of plant cardiotoxins, including sodium channel-activating *Aconitum* (monkshood) species and cardiac glycoside-containing *Oleander* species. The authors described a poisoning toxidrome that mimicked digitalis poisoning with varying degrees of atrioventricular conduction blocks and ventricular tachyarrhythmias.¹⁶

In 2003, Peterson and Rasmussen¹⁴ reported a series of 8 patients who ingested foothill death camas (*Zigadenus paniculatus*) bulbs after misidentifying them as wild onion bulbs while hiking in Juab County, Utah. All 8 patients were symptomatic with nausea, abdominal pain, dizziness, syncope, hypotension, and bradycardia, and 3 patients required hospital admission for supportive care.¹⁴ Although poisonings with the sodium channel activators, such as death camas and hellebores (*Veratrum* spp), are refractory to Fab fragments, intravenous atropine and vasopressor administration may benefit patients with symptomatic bradycardia and hypotension.^{15,17,18}

The *Veratrum* species hellebores are also sodium channel openers and can cause significant bradycardia and hypotension on ingestion.^{17,18} In 1990, Jaffe et al¹⁷ in Manchester, New Hampshire, were among the first to

Table 3. Poisonous plants and herbs capable of causing fatal toxicity

<i>Systemic toxicity</i>	<i>Plant poisons</i>	<i>Mechanisms of toxicity</i>	<i>Toxidromes</i>	<i>Antidotes; support</i>	<i>Genera/species</i>	<i>Common names</i>
Cardiotoxic	Cardiac glycosides	Inhibit cellular Na/K ATPase, ↑ Ca in myocardium, ↑ vagal tone	Mimics digoxin toxicity: N, V, abdominal pain, sinus and junctional bradycardia, Vtach, Vfib	Digoxin-specific Fab, 10–20 vials	<i>Convallaria majalis</i> <i>Digitalis purpurea</i> <i>Nerium oleander</i> <i>Ornithogalum umbellatum</i>	Lily of the valley Foxglove Oleander Star of Bethlehem
	Sodium channel openers	Open voltage-dependent Na channels causing persistent depolarization in cardiac conduction system and in motor neurons	AV block, bradycardia, ventricular arrhythmias, weakness, fasciculations, paralysis	None; specific antiarrhythmic therapy	<i>Aconitum uncinatum</i> <i>Kalmia latifolia</i> <i>Leucothea</i> spp <i>Lyonia</i> spp <i>Pieris floribunda</i> <i>Rhododendron</i> spp <i>Veratrum viride</i> <i>Zigadenus fremontii</i>	Monkshood, friar cap Mountain laurel Sweet bells Fetter bush Japanese Pieris Azalea, rhododendron Hellebore Death camas
	Sodium and calcium channel blocker with digitalis-like effects	Taxine alkaloids block Na and Ca channels and disrupt Na-K transport like digitalis glycosides	Mydriasis, abdominal pain, weakness, emesis, diaphoresis, seizures, ↓ BP, refractory Vtach, ↑ K	None; digoxin-specific Fab ineffective; amiodarone and NaHCO ₃	<i>Taxus</i> spp.yews only. Paclitaxel, a mitotic inhibitor derived from bark of Pacific yew (<i>T. brevifolia</i>) is used to treat and prevent breast cancer	All evergreen yew trees and shrubs
	Anticholinergic	Block Ach at muscarinic receptors in brain and parasympathetic NS	Fever, dry flushed skin, mydriasis, tachycardia, dysphoria, delirium, ileus, atonic bladder, seizures, paralysis	Physostigmine, 1–2 mg IV; children, 0.02 mg/kg	<i>Atropa belladonna</i> <i>Brugmansia candida</i> <i>Datura stramonium</i>	Deadly nightshade Angel's trumpet Jimson weed

Neurotoxic	Hallucinogenic	Salvinorin A is a complete opioid kappa receptor agonist; lysergimides in morning glory seeds inhibit serotonin reuptake	Inebriation, laughter, depersonalization, dissociation, visual hallucinations, paranoia	None; benzodiazepines	<i>Salvia divinorum</i> Morning glories: <i>Ipomoea tricolor</i> <i>Turbina (Rivea) corymbosa</i> <i>Baptisia</i> spp <i>Caulophyllum thalictroides</i> <i>Conium maculatum</i> <i>Laburnum anagryoides</i> <i>Lobelia siphilitica</i> <i>Nicotiana longiflora</i> <i>Cicuta maculata</i> <i>Coriaria myrtifolia</i> <i>Spigelia marilandica</i> <i>Strychnos nux-vomica</i> (import) <i>Blighia sapida</i> (import)	Diviner's (seer's) sage Heavenly blue morning glory Christmas vine morning glory Wild indigo Blue cohosh Poison hemlock Golden chain Blue lobelia Tobacco Water hemlock Myrtle-leaved sumac Pinkroot Strychnine Ackee fruit tree
	Nicotinic	Stimulate preganglionic nicotinic receptors in the autonomic NS	↑ HR, ↑ BP, sweating, mydriasis, seizures, weakness, paralysis, coma	None; benzodiazepines for seizures		
	Other convulsants	Mechanisms include Ach imbalance, K channel block, false neurotransmitters, GABA antagonism (<i>Cicuta</i> , <i>Strychnos</i>), and hypoglycemia (<i>Blighia</i>)	Generalized tonic-clonic convulsions with loss of consciousness (except <i>Strychnos</i> opisthotonus) and postictal hypertonicity	None; benzodiazepines for seizures		
	Toxalbumins	Block protein synthesis by binding to the intracellular 60S ribosomal subunit	Abdominal pain, diarrhea, hematemesis, rapid multi-system organ failure, especially if abrin or ricin is aerosolized or injected	None; vasopressors	<i>Abrus precatorius</i> (import) <i>Mormodica</i> spp <i>Phoradendron</i> spp <i>Ricinus communis</i>	Jequirty pea, rosary pea Balsam apple, balsam pear Southern mistletoe Castor bean

Table 3 (continued)

Systemic toxicity	Plant poisons	Mechanisms of toxicity	Toxidromes	Antidotes; support	Genera/species	Common names
Cytotoxic	Mitotic inhibitors	Block the polymerization of microtubules causing metaphase arrest of mitosis (used as cancer chemotherapeutics and to reduce inflammation in gout)	N, V, D, oral ulcers, GI bleeding, GI necrosis, initial leukocytosis followed by leukopenia	None; a colchicine Fab not available at present; consider colony-stimulating factors for BM suppression	<i>Colchicum autumnalis</i>	Autumn crocus
					<i>Catharanthus roseus</i> (formerly <i>Vinca rosea</i>)	Periwinkle, vinca
					<i>Podophyllum peltatum</i>	May apple
	Cyanogenic glycosides	Hydrolyzed in GI tract and release CN (or hydrocyanic acid) which blocks mitochondrial electron chain with total cellular energy failure	Delayed abdominal pain, N, V, ↓ mental status, seizures, CV collapse, lactic acidosis, and multisystem organ failure	Correction of acidosis, inotropic support, and antidotal therapy with hydroxocobalamin alone, 5 grams intravenously over 15 minutes; or a combination of intravenous hydroxocobalamin and 25% sodium thiosulfate, 50 ml over 15 min.	<i>Eriobotrya japonica</i>	Japanese plum, loquat (fruit pits)
					<i>Hydrangea macrophylla</i>	Hydrangea
					<i>Malus</i> spp	Apple, crab apple (fruit pits)
					<i>Manihot esculenta</i>	Cassava, tapioca (roots)
					<i>Prunus</i> spp	Apricot, cherry choke cherry, peach, plum (fruit pits)
					<i>Sambucus mexicana</i>	Elderberry (leaves, stems, & roots; cooked berries are edible)
	Pyrrolizidine alkaloids	Hepatically metabolized to pyrroles that damage endothelial linings of hepatic sinusoids and pulmonary vessels with centrilobular hepatic necrosis,	Abdominal pain, jaundice, cirrhosis, hepatic necrosis, hepatoma, coagulopathy, pulmonary and portal hypertension	None; supportive therapy for liver failure, liver transplant	<i>Crotalaria</i> spp	Yellow rattlebox
					<i>Heliotropium curassavicum</i>	Seaside heliotrope
					<i>Senecio</i> spp <i>Sesbania grandiflora</i>	Ragwort, groundsel Scarlet wisteria, scarlet rattlebox

GI/hepatotoxic	Calcium oxalate crystal injectors	hepatic veno-occlusion (Budd-Chiari syndrome), and pulmonary hypertension	Intense oral and pharyngeal pain, salivation, laryngeal edema, upper GI perforation possible (aorto-duodenal fistula has been reported)	Demulcents or cold water, irrigation, viscous lidocaine; endoscopy to rule out mucosal injuries	Caladium spp <i>Dieffenbachia</i> spp <i>Epipremnum (Pothos) aureum</i> <i>Philodendron</i> spp <i>Schefflera (Brassia) actinophylla</i> <i>Spathiphyllum</i> spp	Caladium Dumb cane, mother-in-law's tongue Golden pothos, devil's ivy Philodendron Schefflera, umbrella tree Peace lily, white anthurium
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Ach, acetylcholine; AV, atrioventricular; BM, bowel movement; BP, blood pressure; CN, cyanide (hydrocyanic acid); CV, cardiovascular; D, diarrhea; GABA, gamma-aminobutyric acid; GI, gastrointestinal; HR, heart rate; N, nausea; NS, nervous system; V, vomiting; Vfib, ventricular fibrillation; Vtach, ventricular tachycardia.

report a series of *Veratrum viride* (false hellebore) poisoning cases (n = 6) in New England hikers who ingested false hellebores after misidentifying them as edible herbs. All patients presented with nausea, vomiting, bradycardia, and hypotension.¹⁷ The authors recommended management of hellebore poisonings with atropine administration, supplemented with vasopressors as needed, for symptomatic bradycardia and hypotension.¹⁷

The berries, leaves, and seeds of *Taxus* or yew trees contain cardiotoxic taxine alkaloids with both sodium and calcium channel blocking activities causing digitalis toxicity-like effects after ingestion, especially a predisposition to hyperkalemia and ventricular tachydysrhythmias.¹⁹ Although taxine alkaloids are structurally similar to the digitalis-like plant glycosides, their hemodynamic effects, like those of the sodium channel activators, are refractory to reversal by digoxin-specific Fab.¹⁹

In 2009, Pierog et al¹⁹ reported the case of a 24-year-old man who chewed or swallowed 168 yew berry tree (*Taxus cuspidate*) seeds in a suicide attempt and was later witnessed by his parents to be diaphoretic with seizurelike activity. On arrival at the closest emergency department (ED), the patient was hypotensive, and the electrocardiogram demonstrated ventricular tachycardia that could not be cardioverted.¹⁹ Although intravenous amiodarone, 300 mg, and diazepam, 5 mg, were administered, and an amiodarone infusion at 1 mg/min was instituted, ventricular tachycardia continued with resulting cardiovascular depression.¹⁹ The patient was transferred to a regional intensive care unit, where an intravenous bolus of sodium bicarbonate, 100 mEq, was administered, and a sodium bicarbonate infusion was initiated at 37.5 mEq/hour.¹⁹ The amiodarone infusion was discontinued when the wide complex tachycardia resolved and normal sinus rhythm and blood pressure were restored.¹⁹ The authors could not determine whether the correction of the cardiac tachydysrhythmias in this patient was the result of the amiodarone or sodium bicarbonate boluses and infusions, or their synergism.¹⁹ Intravenous sodium bicarbonate, antiarrhythmics, and, possibly, calcium chloride with vasopressor support may be required to treat the simultaneous sodium and calcium channel blockade caused by the taxine alkaloids in yews and restore blood pressure and tissue perfusion.¹⁹

All cardiotoxic plant poisonings may cause serious dysrhythmias and death and may require intensive care management with intravenous atropine and vasopressor support, antiarrhythmic therapy, temporary cardiac pacing or temporary cardiopulmonary bypass, and few specific antidotes with the exception of digoxin-specific Fab in cases of confirmed cardiac glycoside poisonings.

Figure 1. *Nerium oleander*, a Mediterranean native, contains the cardiac glycoside, oleandrin, in all of its parts. Source: Wikipedia (public domain).

Neurotoxic poisonings

Like cardiotoxic plants, neurotoxic plants have also been mistaken for edible herbs (Queen Anne's lace, parsnip, wild carrot) by hikers and foragers. They have been intentionally ingested for their stimulating, intoxicating, and hallucinogenic effects. The neurotoxic plants include the anticholinergic plants, nicotinic plants, convulsant or epileptogenic plants, and hallucinogenic plants (Table 3). In the United

Figure 2. *Zigadenus freemontii*, death camas, all parts of which are toxic, contains several sodium channel activators that are refractory to reversal with digoxin-specific Fab. Source: Wikipedia (public domain).

States, anticholinergic plant poisoning is frequently caused by several species of 3 closely related plant genera (*Brugmasia*, *Datura*, and *Solandra*) from the nightshade or Solanaceae family that contain combinations of 3 tropane or belladonna alkaloids including atropine, hyoscyamine, and scopolamine (Figure 3). In Europe and Asia, other members of the Solanaceae family, such as nightshade (*Atropa belladonna*) and mandrake (*Mandragora officinarum*), are frequent causes of anticholinergic plant poisonings. All of the tropane alkaloids cause central and peripheral anticholinergic toxidromes when plant parts, especially seeds, are ingested in salads or stews or brewed into teas. The tropane alkaloids inhibit acetylcholine receptors in the brain and parasympathetic nervous system, producing a classic toxidrome of flushed dry skin, fever, tachycardia, mydriasis, blurred vision, ileus, urinary retention, agitation, vertigo, and dysphoria, which may later progress to aggression, confusion, dysarthria, hallucinations, and, potentially, fatal coma.^{20–33}

In 2012, Cikla et al²⁶ reported a series of 9 cases of *A belladonna* berry poisonings in Turkey with all patients presenting with classic anticholinergic syndromes, and 1 patient suffering a subdural hematoma, an unusual complication. The authors noted that the berries of *A belladonna* could be easily mistaken for wild Caucasian blueberries in Turkey.²⁶

Figure 3. *Brugmasia suaveolens*, the angel's chalice or trumpet plant, is a widely cultivated, flowering vine throughout the temperate world, all parts of which contain anticholinergic terpene alkaloids (atropine, hyoscyamine, and scopolamine). Teas brewed from plant leaves or flowers will cause a central and peripheral anticholinergic syndrome with delirium and hallucinations. Source: Source: Wikipedia (public domain).

Another member of the Solanaceae family, mandrake or *M. officinarum*, has been associated with witchcraft, and its berries have long been ingested in Eastern Europe as aphrodisiacs.²⁷ In 2012, Nikolaou et al²⁷ reported the case of a 35-year-old man in Greece who ingested unknown aphrodisiac berries and presented with a classic anticholinergic toxidrome that required 4 days of hospitalization for supportive care. Toxicological analyses of the berries and the patient's urine detected 2 tropine alkaloids, hyoscyamine and scopolamine, and a botanist identified the aphrodisiac berries as mandrake berries.²⁷

In 1985, Hayman²¹ reported a series of 7 cases in Australia of intentional ingestion of the flowers of angel's trumpet, *Datura arborea*, for its intoxicating effects. All patients presented with an anticholinergic toxidrome, and 1 patient tragically drowned while hallucinating.²¹

In addition to other varieties of angel's trumpets (*Brugmasia* and *Datura* spp), another commonly ingested plant containing anticholinergic tropine alkaloids in the United States is *Datura stramonium*, also known as jimsonweed, Jamestown weed, or thorn apple.^{28–33} In 1982, Urich et al²⁸ reported a fatal case of jimsonweed ingestion in a 20-year-old man. In 1997, Dewitt et al³¹ reported a series of 9 cases of jimsonweed poisoning in teens intentionally chewing jimsonweed leaves or ingesting teas brewed from jimsonweed leaves or seed pods (thorn apples) in West Virginia. All patients presented with a classic constellation of anticholinergic effects including tachycardia, dry mouth, mydriasis, blurred vision, hallucinations, confusion, combative behavior, and difficulty urinating.³¹ There were no deaths.³¹ Beside accidental death while intoxicated and subdural hematoma, other serious complications of tropine alkaloid poisoning have included seizures, coma, myocardial infarction, rhabdomyolysis, pancreatitis, and tachyarrhythmias.^{21,26,28}

The management of anticholinergic poisonings may include benzodiazepines for sedation for agitation and beta-blockers for tachydysrhythmias.^{9,10} Physostigmine, an acetylcholinesterase inhibitor (1–2 mg intravenously, repeated as indicated every 30–60 minutes to a maximum total dose of 5–6 mg), can reverse a central anticholinergic syndrome in severe cases with coma and tachydysrhythmias.^{9,10} Most patients will recover within 24 hours with benzodiazepine sedation alone for anxiety and combativeness.^{9,10}

Plants containing nicotine and nicotineline alkaloids, such as anabasine, have also been intentionally chewed or ingested for their stimulating effects.³⁴ The plants containing nicotine and nicotineline alkaloids that have been reported to cause human poisonings include *Conium maculatum* (poison hemlock), *Nicotiana*

glauca (tree tobacco), *Nicotiana tabacum* (smoking tobacco), *Laburnum anagyroides* (golden chain tree), and *Caulophyllum thalictroides* (blue cohosh).^{9,10,34} The nicotinic plant alkaloids act agonistically at nicotinic cholinergic receptors within the autonomic and central nervous systems, neuromuscular junctions, and adrenal medulla.³⁴ Early nicotinic cholinergic toxidromes resemble anticholinergic toxidromes with mydriasis, diaphoresis, restlessness, tremors, tachycardia, hypertension, abdominal pain, and, possibly, seizures.³⁴ The later phases are characterized by bradycardia, hypotension, dyspnea, neuromuscular paralysis, respiratory failure, and cardiorespiratory arrest.^{34–38}

In 1987, Castorena et al³⁵ reported the case of a young adult man found dead in a field in Bexar County, Texas. There was no cause of death apparent at autopsy. The only positive toxicological finding was the presence of anabasine, the major nicotinic alkaloid in tree tobacco (*N. glauca*), in the blood, liver, and other solid organs.³⁵ The authors concluded that the decedent had been lethally poisoned by nicotinic alkaloids in tree tobacco absorbed transmucosally or transcutaneously.³⁵ In addition to gastrointestinal absorption after cigarette ingestions, nicotinic plant alkaloids can also be absorbed rectally in home-remedy enemas with *N. tabacum* (smoking tobacco) and transcutaneously during commercial tobacco harvesting, causing green tobacco sickness.^{9,10,35–38}

The poison hemlock plant, *C. maculatum*, contains several neurotoxic piperidine alkaloids, primarily coniine, and has been used since antiquity as an intentional poison—most notably by the Athenians to execute Socrates.^{9,10,34} Nicotinic plant poisoning after ingestion of poison hemlock will result in initial central nervous system (CNS) stimulation with myoclonus and hyperreflexia progressing to generalized tonic-clonic convulsions followed rapidly by weakness, neuromuscular paralysis, and respiratory failure.^{9,10,34}

The convulsant or epileptogenic plants include water hemlock, strychnine, and ackee or breadfruit.^{36–40} They cause more serious poisonings and deaths after unintentional ingestions than most other poisonous plants worldwide every year because they are perennial weeds that resemble many frequently foraged, edible herbs including Queen Anne's lace, parsnip, wild celery, and wild carrot.^{36–40} Epileptogenic plants cause generalized tonic-clonic seizure activity through several mechanisms including gamma-aminobutyric acid antagonism in the CNS (water hemlock), postsynaptic inhibition of inhibitory glycine receptors in the spinal cord (strychnine), and profound hypoglycemia (imported unripe ackee or breadfruit tree fruit).^{9,10,36–40}

In 1992, a 23-year-old man and his 39-year-old brother were foraging for wild ginseng root in Maine

and identified some similar herbs growing in a swampy area.³⁷ The younger man collected several of the plants and took 3 bites from the root of one. The older man took 1 bite of the root of the same plant (Figure 4).³⁷ Within 30 minutes, the younger man vomited and began to have a seizure.³⁷ Emergency medical personnel arrived 45 minutes after the younger man became ill and found him unresponsive with dilated pupils, cyanotic, profusely salivating, and having tonic-clonic convulsions separated by periods of apnea.³⁷ He was transported to a local ED where he was treated with gastric lavage and activated charcoal.³⁷ Three hours after ingesting the root of the plant, he experienced ventricular fibrillation that could not be reversed and died.³⁷ The older brother presented to the ED with seizures and delirium 2 hours after taking 1 bite of the plant root.³⁷ He was stabilized and recovered uneventfully.³⁷ The plant was later identified by an expert as water hemlock, *C maculata* (Figure 4).³⁷

Unintentional ingestions of the water hemlock plant, *C maculata*, cause most of the fatalities attributed to the misidentification of poisonous plants in the United States and Europe because the plant resembles many edible herbs and roots, including ginseng, parsnip, and wild carrot; it is lethal in very small quantities (2–3 cm of its root); and it grows in low-lying, marshy areas worldwide (Figure 4).^{36–38} According to the US Centers for Disease Control and Prevention:

Water hemlock causes most of the fatalities attributed to misidentification of poisonous plants because the plant is lethal in small quantities, resembles edible plants, and is found throughout North America ... Persons who forage for edible wild plants [need] to be aware of and able to recognize poisonous plants in their area.³⁷

Figure 4. The hollow stem of *Cicuta maculata*, water hemlock, has been used to make toy whistles, which have caused fatal cicutoxin poisonings after oral mucosal contact. Source: Personal collection.

Water hemlock's primary toxin, cicutoxin, is present in all its parts, and reaches its highest concentrations in roots and stems.^{36–39} Oral mucosal contact with toy whistles made from the hollow stems of water hemlock has been associated with deaths in children (Figure 4).^{37,39} Water hemlock poisoning will produce initial abdominal pain and nausea within 15 to 90 minutes followed by vomiting, flushing, diaphoresis, salivation, vertigo, bronchorrhea, dyspnea, and cyanosis.^{9,10,36–39} Loss of consciousness, seizures, and status epilepticus may follow initial symptoms and, if not lethal, may result in rhabdomyolysis, myoglobinuria, and acute renal failure.^{9,10,36–39}

Although derived from a nonnative Asian plant, *Strychnos nux-vomica*, strychnine is now cultivated in Hawaii and has been used for decades in the United States and Southeast Asia as a rodenticide, antiparasitic, antipyretic, and heroin adulterant.^{9,10,40} Strychnine poisoning is unique among epileptogenic plant poisonings because it causes initial CNS stimulation manifested by fasciculations and hyperreflexia followed by severe tonic-clonic muscle spasms with opisthotonic posturing without loss of consciousness.^{9,10,40} Severe muscular spasms can result in tendon ruptures and vertebral fractures and are often associated with hyperpyrexia, rhabdomyolysis, and acute renal failure.^{9,10,40} There are no antidotes for the epileptogenic plant poisonings, and successful management strategies have included early airway protection and sedation and muscular relaxation with benzodiazepines and neuromuscular blockers, especially in strychnine poisonings.^{9,10} Additional supportive care with mechanical ventilation and hemofiltration or hemodialysis for renal failure are often indicated in severe cases.^{9,10,36}

The frequently abused hallucinogenic plants include the herb diviner's sage (*Salvia divinorum*) and morning glory vine, especially its seeds.^{7,41} Although now banned by several countries and controlled in most US states, *Salvia* or *S divinorum* is often marketed on the Internet as a legal alternative to marijuana and illicit drugs.^{3,12} The psychoactive agent in *Salvia* is salvinorin A, a diterpene and selective kappa-opioid receptor agonist, which produces psychomimetic effects after ingestion of teas brewed from leaves resembling the adverse effects caused by serotonergic agonists, selective serotonin reuptake inhibitors, and *N*-methyl-D-aspartate glutamate (NMDA) antagonists.⁴²

The psychoactive agents in morning glory seeds include the ergot alkaloids, ergonovine and lysergic acid amide, which resemble lysergic acid diethylamide stereochemically and cause similar psychomimetic effects.^{9,10} Morning glory seeds, like *S divinorum*, may also be purchased on the Internet, but unlike *Salvia*, have not

been criminalized.^{9,10} The psychedelic effects of *Salvia* leaf teas and morning glory seeds or brews are similar with blunted affect, déjà vu, dissociation, uncontrollable laughter, multidimensional motion sensation, merging objects, colorful visual hallucinations, and paranoia.^{7,42} There are no antidotes for *Salvia* and morning glory seed intoxication, and sedation with benzodiazepines and antipsychotics are often indicated.^{3,9,10,42}

Cytotoxic poisonings

The cytotoxic plants include 1) the toxalbumins, the toxin (ricin) of one of which, the castor bean (*Ricinus communis*) has been weaponized; 2) the mitotic inhibitors, many of which are highly effective as cancer chemotherapeutics; and 3) the cyanogenic plant glycosides contained in the kernels of several fruits, including apples, apricots, cherries, peaches, and plums (Table 3). Many are popular household (crocus) and garden (crocus, vinca) plants that have been used to make anti-inflammatory drugs (colchicine from crocus) and jewelry (castor bean, jequirity or rosary pea) and to treat cancer (vinblastine and vincristine from vinca, podophyllotoxin from mayapple).

The toxalbumins are all plant lectins usually concentrated in seeds that inhibit protein synthesis by binding to intracellular 60S ribosomal subunits and resulting in initial gastrointestinal toxicity followed by multiorgan failure.^{41,43–49} The toxalbumin-containing plants include the castor bean plant (*R. communis*), formerly grown commercially for castor oil-containing pharmaceuticals and motor oils; the jequirity pea or rosary plant (*Abrus precatorius*), a Caribbean tropical vine introduced into South Florida; the balsam apple (*Mormordica* spp), a tropical, creeping vine with fruit used in home remedies topically for wound healing and orally for diabetes; and several varieties of mistletoe (*Phoradendron* spp), the parasitic epiphytes of deciduous trees and popular Christmas decorations.^{9,10,41,43–49}

Ricin and abrin can be released in highly toxic amounts when the hard seeds of castor bean plants or jequirity pea vines are chewed, swallowed, and ingested, or when these toxalbumins are weaponized for injection or for aerosolization.^{42–49} Both castor bean and jequirity pea seeds are still used by Caribbean and West African folk artists to make colorful jewelry and rosary beads that are frequently imported and may be accidentally ingested by children (Figures 5 and 6).^{8,41,43–49} As long as seeds are not chewed before ingestion, they will not release their toxalbumins and cause significant gastrointestinal toxicity.^{8–10} There are no antidotes or vaccines for toxalbumin toxicity, and management of poisonings must begin immediately with intravenous fluid

Figure 5. Colorful *Ricinus communis* or castor bean seeds often used in tropical native jewelry will release the toxalbumin, ricin, a powerful protein synthesis inhibitor, when chewed, with severe gastrointestinal toxicity and potential multisystem organ failure. However, the ingestion of intact seeds does not cause toxicity and will not require therapy. Source: United States Department of Agriculture (USDA).

resuscitation and vasopressor support for cardiovascular collapse.^{43,44}

Ricin is among the most lethal natural toxins known, and the castor bean plant, *R. communis*, from which it can be easily obtained, grows throughout the world. The lethal dose of ricin may be as little as 500 µg or 4 chewed beans in an adult and 3 chewed beans in a child.^{43,45} Ricin gained attention as a weapon when a ricin pellet fired by an umbrella gun was used to assassinate Bulgarian dissident Geogi Markov in London

Figure 6. Colorful *Abrus precatorius* or jequirity or rosary pea seeds often used in tropical native jewelry will release the toxalbumin, abrin, when chewed, with severe gastrointestinal toxicity and potential multisystem organ failure. However, the ingestion of intact seeds does not cause toxicity and will not require therapy. Source: United States Department of Agriculture (USDA).

in 1978.^{43,44} In additional criminal uses, ricin has reputedly been weaponized for aerosol dispersion.⁴³

In 1986, Wedin et al⁴⁴ reported 2 cases of ricin poisoning in children in the United States who had chewed and swallowed brightly colored castor beans (Figure 5). The patients presented with repeated vomiting, diarrhea, dehydration, and elevated serum creatinine levels.⁴⁴ The children recovered uneventfully with supportive care.⁴⁴ In 2012, Assiri⁴⁵ reported the fatal case of a 42-year-old Saudi man who ingested an herbal mixture containing castor bean powder and presented with bloody diarrhea and hypovolemic shock that progressed to cardiorespiratory arrest.

Abrin contained in jequirity or rosary pea seeds is another natural toxalbumin with a lethal dose in man as low as 0.1 to 1.0 µg/kg.^{47–49} Most cases of abrin poisoning have occurred after chewing and swallowing the very colorful *A. precatorius* (rosary pea) seeds (Figure 6).^{47–49} In 2015, Alhamdani et al⁴⁹ reported the case of an 18-month-old boy who presented to the ED with abrupt onset of fever, vomiting, diarrhea, and dehydration. The parents observed 3 consecutive diapers that contained colorful red seeds with black end bands later identified by the regional poison control center as *A. precatorius* seeds (Figure 6).⁴⁹ The child recovered uneventfully with intravenous rehydration and supportive care.⁴⁹

Rosary pea seeds have been chewed and swallowed intentionally in suicide attempts.^{47,48} In 2008, Sahoo et al⁴⁷ reported the case of a 19-year-old man in India who ingested crushed rosary pea seeds after a family quarrel and presented with abdominal pain, vomiting, and bloody diarrhea, followed by mental status changes and seizures. Magnetic resonance imaging of the brain demonstrated demyelination bilaterally in the medial temporal lobes, an unusual complication of abrin poisoning.⁴⁷ The patient recovered uneventfully after corticosteroid therapy and supportive care.⁴⁷

Today, rosary pea seeds can be easily obtained over the Internet.⁴⁸ In 2015, Jang et al⁴⁸ reported the attempted suicide in a 20-year-old man who chewed and swallowed 10 rosary pea seeds that he had obtained by mail order over the Internet. He presented to the ED with vomiting and watery diarrhea for 6 to 8 hours.⁴⁸ The patient recovered uneventfully with supportive care and was discharged to outpatient psychiatric follow-up.⁴⁸

The indigenous plants containing mitotic inhibitors include autumn crocus (*Colchium autumnalis*), vinca or periwinkle (*Catharanthus roseus*), and mayapple (*Podophyllum peltatum*).^{9,10,50,51} The mitotic inhibitors all contain similar cytotoxic plant alkaloids that can inhibit polymerization of microtubules and cause metaphase arrest of mitosis, especially in rapidly dividing cells in

the gastrointestinal tract and bone marrow.^{9,10} Cytotoxic alkaloids derived from these plants have been used to treat gout (colchicine), condylomata acuminata (podo-phyllin), and cancer (vinblastine, vincristine, paclitaxel, podophyllotoxin).^{9,10,50} Ingestions of any parts of these plants will cause initial oropharyngeal pain followed by severe gastrointestinal symptoms within hours, including intense abdominal pain and severe, profuse, and persistent diarrhea that may lead to volume depletion and electrolyte imbalance.^{9,10,50} Delayed toxic effects may include bone marrow toxicity, manifesting initially as leukocytosis followed by leukopenia, peripheral neuropathy, ataxia, seizures, and encephalopathy.^{9,10,50} Death may result from direct toxic effects, coagulopathy, cardiovascular collapse, or latent sepsis.^{9,10,50} There are no antidotes for mitotic inhibitor toxicity, and management of poisonings must begin immediately with intravenous fluid resuscitation and vasopressor support for cardiovascular collapse.^{9,10,50}

In 2015, Boisramé-Helms et al⁵⁰ reported the case of a 68-year-old woman who had picked, cooked, and eaten leaves of colchicine-containing *Colchium autumnale* (autumn crocus) that she had mistaken outdoors for edible wild leeks. A few hours later, she developed abdominal pain, nausea, vomiting, and diarrhea with dehydration.⁵⁰ By day 3, the patient had developed cardiogenic shock with multiorgan failure and was admitted to a regional intensive care unit with a mean arterial pressure of 50 mm Hg and left ventricular ejection fraction of 5% to 10%.⁵⁰ Mechanical ventilation and venous-arterial extracorporeal life support (ECLS) were instituted for cardiogenic shock refractory to vasopressors.⁵⁰ Pancytopenia and coagulopathy developed on day 4 and required massive transfusion with blood products including red blood cell (15 units) and platelet (13 units) concentrates and 7 units of fresh-frozen plasma.⁵⁰ By day 10, coagulation and cardiac status had been restored, and the patient was weaned from mechanical ventilation and ECLS.⁵⁰ The authors concluded that ECLS might be useful as a bridge to recovery in severely poisoned patients with colchicine poisoning and refractory circulatory shock.⁵⁰

Many edible fruits of the *Malus* (apple, crabapple) and *Prunus* (apricots, cherries, peaches, plums) species contain cyanide-releasing glycosides within their kernels.^{9,10} In addition, some ornamental plants, such as hydrangeas, and even trees (elder) also contain cyanogenic glycosides in their flowers (hydrangeas) or leaves, stems, and roots (elder).^{9,10,51} After ingestion of toxic parts of cyanogenic plants, cyanogenic glycosides have to be hydrolyzed in the gastrointestinal tract before they release cyanide ion, which inhibits the final step in the mitochondrial electron transport chain and causes cytotoxicity from limited

adenosine triphosphate production and cellular energy failure.^{9,10,51} After an incubation period of several hours, a constellation of lethargy, diaphoresis, abdominal pain, nausea, and vomiting ensues and is followed by mental status changes, ataxia, vertigo, stupor, seizures, cardiovascular instability, and multisystem organ failure.^{9,10,51}

On August 26, 1983, 8 persons with acute gastrointestinal (acute abdominal pain, nausea, vomiting) and neurological (weakness, dizziness, numbness, stupor in 1 patient) were evacuated from a remote, rural religious center in Monterey County, California, to a regional hospital for treatment of possible cyanide poisoning.⁵¹ On arrival, all patients had normal arterial blood gases, received supportive care with rehydration, and were discharged uneventfully the next day.⁵¹ Two days before the outbreak, religious center staff had prepared a fruit juice drink in a stainless steel press made from the crushed berries, leaves, and stems of elder trees, *Sambucus mexicana* (Figure 7).⁵¹ The juice was served the next day to a group of 25 people, and the severity of the presenting symptoms was correlated with the amount of fruit juice consumed.⁵¹ Those who drank tea only remained well.⁵¹

The elder tree is indigenous to the Western United States and produces globular black berries that are edible when mature (Figure 7).⁵¹ Elderberry extracts are used in fruit juices, cough and cold syrups, and alcoholic beverages, and cooked elderberries are used in jams and pies.⁵¹ Elder tree leaves, stems, bark, and roots all contain cyanogenic glycosides that can release hydrocyanic acid in the gastrointestinal tract.⁵¹ Although elderberries are safe to consume, especially

Figure 7. Ripe elderberries on the American elder tree, *Sambucus mexicana*. Although the ripe berries are edible and often used in juices and jams, the leaves, stems, bark, and roots of elderberry trees contain cyanogenic glycosides capable of causing symptomatic cyanide poisoning. Source: Wikipedia (public domain).

when cooked, the leaves, stems, and roots should not be crushed when preparing juices from wild elderberries.⁵¹

Laboratory results in cyanide poisoning will demonstrate lactic acidosis and elevated cyanide and thiocyanate levels.^{9,10} Initial management should include correction of acidosis, inotropic support, and antidotal therapy with hydroxocobalamin alone, 5 g intravenously over 15 minutes, or a combination of intravenous hydroxocobalamin and 25% sodium thiosulfate, 50 mL over 15 minutes.^{9,10}

Gastrointestinal/hepatotoxic poisonings

The plants causing gastrointestinal toxicity include the hepatotoxic pyrrolizidine alkaloids and the calcium oxalate injectors, which are popular household plants and include many cultivars of *Caladium*, *Dieffenbachia*, *Philodendron*, *Schefflera*, and *Spathiphyllum*.^{9,10,52,53} Because intense oropharyngeal pain from mucosal injection of calcium oxalate crystals will limit further ingestion, chewing, and swallowing, most calcium oxalate plant ingestions are not very hazardous and can be managed with copious irrigation, demulcents, viscous lidocaine, and oral analgesics.^{9,10,52} Ocular exposures to the sap of calcium oxalate-containing plants may cause severe eye pain, which should be managed with copious irrigation, topical anesthesia, and referral to an ophthalmologist for slit-lamp evaluation and follow-up, if indicated.^{9,10,52}

For many years, there was consensus that the scientific literature ascribed significantly more morbidity to household *Dieffenbachia* (dumb cane) exposures than could be supported by observations made by experienced clinical practitioners.⁵² In a study designed to determine whether the symptoms of *Dieffenbachia* exposures described in case reports and published in the scientific literature were consistent with years of clinical experience, Pedaci et al⁵² conducted an Internet-based comparative study of 23 published reports of *Dieffenbachia* exposures with the symptom information obtained from the AAPCC TESS database for the period 1993–1996. There were some consistent similarities in the symptoms of *Dieffenbachia* exposures reported in the literature and in the TESS data, eg, the concordance of oral irritation was 92.6% in the case reports vs 18.2% in the TESS data.⁵² Similar wide disparities, however, continued throughout the concordances between other symptoms reported in the scientific literature vs the TESS data, such as throat irritation (22.2% vs 2.3%), ocular irritation (44.4% vs 1.7%), and many others.⁵² The closest concordances were in dermal edema (3.7% vs 2.2%), dermal erythema (5.3% vs 2.5%), and cough/choke (3.7% vs 1.1%).⁵² The authors of the study concluded that the scientific

literature did indeed portray *Dieffenbachia* exposures as associated with more morbidity than what was reported in the AAPCC TESS clinical practice database.²³

Despite the findings of the study by Pedaci et al,⁵² Snajdauf et al⁵³ later (2005) reported a case of an aortoesophageal fistula with exsanguinating hemorrhage in a 12.5-year-old girl 5 weeks after eating 1 leaf of *Dieffenbachia picta* in a suicide attempt. Emergency exploration of the cervical esophagus, laparotomy, and thoracotomy were required to identify the source of the massive gastrointestinal hemorrhage as an aortoesophageal fistula between the ascending aorta and thoracic esophagus, control the bleeding surgically, and save the child's life.⁵³ Although calcium oxalate injectors rarely cause potentially fatal poisonings, they are responsible for the most frequent plant ingestions, rarely with any serious consequences, and have been used in suicide attempts.^{9,10,52,53}

The indigenous plants containing pyrrolizidine alkaloids in all parts include the very fragrant and popular ornamental house and garden species of *Crotalaria* (yellow rattlebox) and *Sesbania* (scarlet rattlebox).^{9,10,54} Chronic low-dose ingestions of plant pyrrolizidine alkaloids in herbal teas and dietary supplements may result in insidious hepatotoxicity from veno-occlusive disease indistinguishable from the Budd-Chiari syndrome.⁵⁴ After ingestion, the pyrrolizidine alkaloids are hepatically metabolized to highly alkaline pyrroles that can cause caustic burns of the lining epithelium of hepatic sinusoids and, less commonly, of pulmonary vessels.^{9,10,54} Massive acute ingestions can cause right upper quadrant pain, acute hepatitis, ascites, elevated liver enzymes, and coagulopathy.^{9,10,54} Chronic low-level exposures may result in cirrhosis, hepatic veno-occlusive disease, and pulmonary hypertension.^{9,10,54} There are no antidotes for pyrrolizidine toxicity; supportive management may allow time for hepatic regeneration, and hepatic transplantation may be indicated for acute or chronic liver failure.^{9,10,54}

POISONINGS BY UNKNOWN PLANTS

Because most plant exposures are to nontoxic plants or to relatively nontoxic amounts of toxins in poisonous plants, the general management of poisonings by unknown plants should be supportive and based on the 4 presenting toxidromes. With the exception of animal-derived digoxin-specific Fab antibodies (Digibind, Digifab) to inactivate ingested plant-derived cardiac glycosides and physostigmine to reverse plant toxin-induced central anticholinergic syndromes, there are few effective antidotes for most plant toxins. Most gastrointestinal decontamination techniques for management of plant

poisonings are no longer indicated. Oral activated charcoal administration may be indicated if the poisoned patient is conscious, alert, and cooperative, and presents within 60 minutes of potentially dangerous or lethal plant ingestions. Whole bowel irrigation does offer an opportunity to completely cleanse the gastrointestinal tract of poisonous plant matter but should be reserved only for patients who have ingested significant amounts of poisonous plant matter that will release toxins slowly over time in the gastrointestinal tract such as chewed apple, cherry, or apricot kernels containing cyanogenic glycosides or oleander seeds containing cardiotoxic glycosides. Severe poisonings with cardiotoxic plants, toxalbumins, and colchicine may result in cardiovascular collapse and multiorgan failure and require extracorporeal life support.

Conclusions

Colorful cultivated and wild plants and their fruits and seeds, some of which may be highly toxic, will continue to attract the mouthing behaviors of infants and toddlers.^{44,49} Teenagers will continue to experiment with naturally hallucinogenic plants.^{30–32,42} Even experienced trekkers, foragers, and chefs may occasionally misidentify poisonous plants and herbs as edible. A simple toxidromic classification system of plant poisonings designed for urgent-care first-responders may permit more rapid differential diagnoses of highly toxic vs nontoxic plant ingestions both in households and outdoors, direct earlier management of potentially serious plant ingestions, and reduce costly inpatient evaluations for inconsequential plant ingestions. Validation of a rapid toxidromic classification system as compared with existing, cumbersome classification systems for plant poisonings will require future adoption and implementation of the toxidromic system by its intended users with time.

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