Poisoning in donkeys

Poisoning in donkeys is occasionally reported, but most of the information on clinical signs and management is based on horses. Donkeys are most likely to be affected by toxic substances in their environment such as poisonous plants and pesticides. Cases of plant poisoning in donkeys have been reported, caused by yew, oleander, oak, *Brunfelsia* and plants containing hypoglycin A (such as sycamore), cyanogenic glycosides (such as cherry laurel) or pyrrolizidine alkaloids (such as ragwort or rattlepods). In many cases of acute plant poisoning, sudden death is the presenting sign. Pesticide poisoning risks include metaldehyde slug bait and anticoagulant rodenticides. Care should be taken when examining and treating donkeys because of differences in their behaviour, vital signs, laboratory parameters and therapeutics. Donkey-specific resources should be used. Treatment in most cases of poisoning in donkeys is supportive, with management of clinical signs and attempting to reduce progression of toxicosis, removal from exposure, and specific antidote administration where available, practical and clinically appropriate.

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Just as with horses, donkeys are at risk of poisoning from plants and substances in their environment, such as pesticides. Although more information is available on poisoning in horses, cases of toxicosis in donkeys are reported.

When performing a clinical assessment on a donkey it is important to take into account their specific behaviour and not view them as small horses. Blood biochemistry, haematology and vital signs in donkeys are different to those of horses and specific reference resources should be consulted (Olmos et al, 2011; Burden and Thiemann, 2015; Haines and Goliszek, 2019; *Box 1*). Signs of pain, for example, can be subtle in donkeys and may be missed. Pain assessment scales specific for donkeys are available and can be used to monitor pain and improve welfare (van Dierendonck et al., 2020). Donkeys are also prone to hyperlipaemia and there are numerous risk factors (Burden et al., 2011); ill or stressed donkeys must be monitored for hyperlipaemia which can progress rapidly and must be treated promptly (*Box 1*). Hyperlipaemia is a common complication of almost any primary disease in donkeys and worsens the prognosis (Archer et al, 2021). In addition, it is important to remember that donkeys may become stressed when separated from a bonded companion and this may contribute to behavioural changes and clinical signs.

As grazers and browsers, donkeys are at risk of poisoning from toxic plants. They evolved in an environment that is vegetation poor and may eat plants that horses find unpalatable. Common poisonous plants are discussed below, and other plants are outlined briefly in *Table 1*. Prevention of poisoning in donkeys is outlined in *Box 2*.

There is limited information on the pharmacology of many drugs in donkeys and mules, owing to a lack of specific studies (Burden and Thiemann, 2015). Donkeys evolved in a desert environment and can tolerate a degree of dehydration without harm. This adaptation means there are differences in fluid balance, water partitioning and drug clearance in donkeys compared to horses. Metabolism of many drugs is generally more rapid in the donkey, and although the dose may be the same as in horses, the dosing intervals may be more frequent. Donkey-specific dosing regimens should be used where available (*Box 1*).

Box 1. Donkey-specific resources

The Donkey Sanctuary website is a valuable source of material on donkey care and behaviour for owners and veterinary professionals.

- https://www.thedonkeysanctuary.org.uk

Yew

Yew (*Taxus* species, *Figure 1*) is a common cause of plant poisoning in livestock and equids. The main toxic component is taxine, a complex mixture of alkaloids. Taxines are rapidly absorbed from the gut and interfere with sodium–potassium transport mechanisms resulting in cardiac effects; they reduce atrioventricular conduction resulting in bradycardia and arrest. *Taxus* species also contain an irritant volatile oil, present throughout the plant, which can cause gastrointestinal irritation and diarrhoea.

Poisoning can occur at any time of the year and plant material is still toxic after drying. Most cases of poisoning in animals occur as a result of accidental ingestion of hedge trimmings or grazing on yew. Cases of poisoning have been reported in donkeys eating dried plant material (Veterinary Poisons Information Service [VPIS] case data). Yew is not thought to be palatable and is more likely to be ingested in stressed or malnourished animals, or where it has been mixed with a more palatable material, such as grass. In an experimental study, a cow, a goat, three sheep and two horses

Table 1. The clinical signs and toxic principles in other poisonous plants not covered in detail

Plant	Toxic principle	Potential clinical signs
Acer rubrum (red maple)	Gallic acid (possibly)	Clinical signs include tissue hypoxia, anaemia and methaemoglobinaemia with anorexia, lethargy, dehydration, depression, tachycardia, tachypnoea, yellow or brown mucous membranes, jaundice, brown discolouration of blood and red or dark discolouration of urine. Complications of hypoxia, hypoperfusion or systemic inflammation include colic, laminitis, hyperthermia and disseminated intravascular coagulation. Severe hypoxia can result in arrhythmias and convulsions
Allium species (onion, garlic, leek, ornamental allium)	Organosulphoxides, including n-propyl disulphide, allyl propyldisulphide and allyl sulphide	Clinical signs are those generally associated with haemolytic anaemia. Severe dermatitis has also been reported in a horse
Atropa belladonna (deadly nightshade), *Datura stramonium* (jimson weed)	Tropane alkaloids, hyoscyamine (L-atropine), atropine (DL-hyoscyamine), and scopolamine (hyoscine)	Hyperexcitability, hyperthermia, dilated pupils, ataxia, tachypnoea, colic, tachycardia, dry mucous membranes, dyspnoea, convulsions and coma
Colchicum autumnale (autumn crocus)	Colchicine, an alkaloid amine	Signs in other animals include severe gastrointestinal irritation, dehydration, recumbency, collapse, shock, hyperthermia, renal impairment and bone marrow depression
Conium maculatum (hemlock)	Coniine, a piperidine derivative	Signs in other animals include dullness, inappetence, thirst, hypersalivation, hypothermia, tremor, weakness, cessation of milk production, convulsions and renal impairment
Juglans nigra (black walnut)	Unknown	Laminitis
Laburnum anagyroides (laburnum)	Quinolizidine alkaloids	Ataxia, sweating, tremors, colic, muscle contractions and coma
Ligustrum species (privet)	Unknown but usually referred to as ligustrin, a glycoside	Dilated pupils, colic, bradycardia or tachycardia, congested mucous membranes, ataxia and recumbency
Mercurialis perennis (dog's mercury), *Mercurialis annua* (annual dog's mercury).	Saponins, volatile oils	Jaundice and haemoglobinuria may occur
Oenanthe crocata (hemlock water dropwort)	Oenanthotoxin, a long chain polyacetylenic alcohol	Signs in other animals include hypersalivation, abdominal discomfort, tremor, dilated pupils, bradycardia, ataxia, convulsions and respiratory failure
Pteridium species (bracken) *Equisetum* species (horsetail)	Thiaminase, an enzyme	Induced avitaminosis B1 with chronic ingestion in monogastric animals with depression, constipation and ataxia and lack of co-ordination (bracken staggers). As the disease progresses (generally over 2–7 days) there is loss of condition, weakness, inability to stand, nervousness, severe muscle tremors, convulsions and opisthotonus
Rhododendron species (including azaleas), *Pieris* species	Grayanotoxins, neurotoxins	Initially gastrointestinal signs are predominant with copious salivation, regurgitation and severe colic. Depression, tremor, bradycardia, weakness, ataxia, staggering and recumbency. In severe cases, tachypnoea, hypotension, pyrexia, opisthotonus and convulsions may occur
Robinia pseudoacacia (black locust or false acacia)	Robin (or robinia) and phasin, lectins; robitin, a glycoside	Common in horses, often from ingestion of bark which has a sweet liquorice taste. A small dose causes gastrointestinal signs only, but a large quantity can result in neurological effects Abdominal pain, diarrhoea, weakness, depression, dilated pupils, tachycardia, reduced or absent bowel sounds, hyper- or hypothermia, laminitis, tremor, muscle spasms, elevated liver enzymes and hyperammononiaemia. In severe cases, nystagmus, head pressing and ataxia, progressing to dyspnoea, recumbency, coma, increased muscle tone, spastic limbs, trismus and convulsions

all refused to eat yew clippings when given hay and clover (Alden et al, 1977). In an experimental study, 120g of ground material from *Taxus cuspidata* was fatal within 1.5 hours in a Shetland pony (Lowe et al, 1970). A dose of 200–400 mg/kg of yew leaves is reported as a minimal lethal dose in horses (Ogden, 1988; Wilson et al, 2001; Tiwary et al, 2005).

Clinical signs

The onset of signs after ingestion of yew is variable; death can occur within 2–36 hours, but usually within 24 hours. Clinical signs in horses include colic, diarrhoea, ataxia, bradycardia, trembling, weakness, collapse, respiratory distress and recumbency, and sudden death (usually caused by cardiac arrest) can occur. Convul-

Box 2. Prevention of poisoning in donkeys

- Store products, such as pesticides and medicines, securely and store feedstuffs separately
- Clean up spills promptly
- Ensure fencing is secure to prevent escape. Donkeys will escape if they can
- Allow free access to fresh water at all times
- Weigh animals accurately to ensure correct dosing of drugs with a narrow therapeutic index

Client education:

- Prevent access to areas with poisonous plants, particularly at times of increased risk of poisoning (such as during high winds, lack of forage, fruiting season)
- Ensure access to adequate forage
- Prevent access to clippings from hedge/tree trimmings or overhanging branches
- Avoid planting and remove any toxic plants near or adjacent to or in donkey pastures
- Burn clippings or dispose of safely away from donkeys
- Do not allow donkeys access to areas containing poisonous plants that have been treated recently with herbicide (this can make plants more palatable)
- Regularly check pastures, enclosures and boundaries for potential access to poisonous plants
- Maintain enclosures to prevent escape and free-range access to potentially poisonous plants in woods, gardens and other areas
- Avoid overgrazing of pastures which can promote growth of some toxic plants
- When moving animals between grazing areas or yards, ensure they do not graze on poisonous plants en route
- Know your poisonous plants, including seasonal risks.

*Figure 1. Yew (*Taxus *species) can cause sudden death in donkeys.*

sions are rare. Most symptomatic cases are fatal and death can occur within a few minutes of the onset of clinical signs.

Treatment

There is no specific antidote and treatment of animals with yew poisoning is supportive. Activated charcoal (*Box 3*) can be given if ingestion was recent, but many animals are found dead after ingesting yew. In animals with bradycardia, it should be noted that atropine does not always work, and will also slow peristalsis and delay elimination (Hare, 1998).

Hypoglycin A

It is well recognised that horses can develop hypoglycin A poisoning after grazing some *Acer* species, but there is increasing evidence that other equids including donkeys and other herbivores are also at risk (van Galen, 2008; van Galen et al, 2012a; Renaud et al, 2022).

Atypical myopathy is a muscle disease with a high mortality. It is associated with chronic ingestion of seeds or seedlings of some *Acer* species including sycamore (*Acer pseudoplatanus*, *Figure 2*) and ashleaf maple (box elder, *Acer negundo*). These plants contain hypoglycin A (McKenzie et al, 2016) which prevents the oxidation of fatty acids and therefore the production of energy in mitochondria (Votion, 2016). Type 1 muscle fibres (found in cardiac, respiratory and postural muscles), which are more dependent on fatty acid oxidation for energy needs, are affected.

Clinical effects

Signs are caused by acute degeneration in postural and respiratory muscles and sometimes the myocardium (Votion et al, 2014). Death can occur from cardiac or, more commonly, respiratory failure (Rendle, 2016).

Initial signs of poisoning include reluctance to move and quiet demeanour. Signs then progress to pronounced muscle weakness (with stiffness, dysphagia, recumbency and respiratory distress) and pain (sweating, depression, gastrointestinal impaction). Tachycardia may result from cardiomyopathy and/or pain. Pigmenturia with a dark red/brown urine occurs in the majority of cases (Rendle, 2016).

Hyperlipidaemia and hyperglycaemia occur (owing to stress, catabolism, impaired lipid metabolism, reliance on carbohydrate metabolism and increased hepatic gluconeogenesis). Secondary complications are common, with subcutaneous oedema of the head, pressure ulcers, buccal ulceration, gastric ulceration, choke, diarrhoea, renal dysfunction, paraphimosis and corneal ulceration.

The mortality rate in donkeys is unknown but in horses with hypoglycin A poisoning, mortality is high and many die within 2–3 days of the onset of signs (van Galen, 2008; Votion, 2012). The mortality in individual incidents is very variable and has been reported as 56–96% (Bates, 2022). The survival rate is generally around 25% but it is worth noting that this includes cases that occurred before the mechanism of poisoning was understood and targeted treatment was applied. Horses that survive beyond 5 days have a better prognosis (van Galen et al, 2010) and there appear to be no long-term sequelae (Valberg, 2014; Rendle, 2016).

Treatment

Treatment of atypical myopathy is supportive and should be started as soon at the disease is suspected. Any affected donkey with suspected atypical myopathy and any companion animals, or those in the same pasture, should be removed from possible exposure. The aims of therapy in animals with atypical myopathy are: limiting further muscle damage, restoring circulating volume, correcting acid–base and electrolyte disturbances, providing alternative energy substrates to muscle cells and analgesia (Votion, 2016).

Renal, liver and respiratory function, and levels of triglycerides, creatine kinase, lactate dehydrogenase and aspartate aminotransferase, electrolytes and glucose should be monitored. An electrocardiogram and troponin concentrations should be monitored for evidence of myocardial dysfunction (van Galen and Votion, 2013). Subclinical toxicosis is common and creatine kinase levels should be measured in any herd mates of a suspected case (Durham, 2015).

Fluid therapy is important in affected animals with atypical myopathy as it will correct dehydration and acid–base disturbances, and protect the kidneys from myoglobin-induced injury and non-steroidal anti-inflammatory drug (NSAID)-induced renal effects (van Galen and Votion, 2013a; Fabius and Westermann, 2018). In atypical myopathy, there is impaired lipid metabolism and a shift from aerobic and anaerobic metabolism and metabolites from anaerobic metabolism derange homeostasis. Nutritional support should therefore focus on providing an alternative energy source (such as carbohydrates) and providing a low-fat diet. Carbohydrate-rich foods include grass, good quality hay, alfalfa, grains, molasses, carrots and apples. Food should be given little and often to prevent large fluctuations in glucose levels, with free access to grass, hay or alfalfa (van Galen et al, 2012b). In anorexic or dysphagic donkeys, a stomach tube may be required (van Galen et al, 2012b). Supplements including vitamin E, selenium (Finno et al, 2006; van Galen et al, 2012b), carnitine (Fabius and Westermann, 2018) and vitamin B2 (riboflavin) (Fabius and Westermann, 2018) may also be helpful in animals with atypical myopathy.

Animals with atypical myopathy should be kept warm (Votion et al, 2007) and stress limited where possible. Analgesia may be required and is recommended in animals with recumbency as pain relief may allow them to stand.

Cyanogenic glycosides (such as cherry laurel)

Many plants contain cyanogenic glycoside compounds, but most cases of poisoning occur following ingestion of plants from the Rosaceae (rose) family, particularly the genus *Prunus* which includes, cherry laurel (*Prunus laurocerasus*, *Figure 3*) and Portuguese laurel (*Prunus lusitanica*).

Ingestion (and grinding, chewing or crushing) of plant material containing cyanogenic glycosides results in the formation of hydrogen cyanide. Small doses of cyanogenic glycoside compounds can be tolerated because of detoxification mechanisms (the conversion of cyanide to thiocyanates by rhodanese), but ruminants appear to be more susceptible than monogastric animals because of the speed with which ruminal hydrolysis can release hydrogen cyanide.

Poisoning with *Prunus virginiana* (Virginia bird cherry, chokecherry, an American species) has been reported in donkeys. One

Box 3. Activated charcoal

- Dose is 1–4 g/kg mixed with warm water to form a slurry, given via stomach tube
- Repeated doses can be given if required
- A laxative can be given after the first dose to hasten passage through the gut
- Activated charcoal is a finely powdered material that has been treated to give it a huge surface area (1000 m2/g), which is capable of binding a variety of drugs and chemicals
- It binds many toxic substances and reduces gastrointestinal absorption
- Activated charcoal is not systemically absorbed or metabolised but passes through the gut.

*Figure 2. Sycamore (*Acer pseudoplatanus*) contains hypoglycin A which causes atypical myopathy in herbivores.*

*Figure 3. Cherry laurel (*Prunus laurocerasus*) contains cyanogenic glycosides which can cause cyanide toxicosis and sudden death in herbivores.*

(220 kg) had been found dead and another (70 kg) staggering and collapsing before dying a few minutes later. At post-mortem examination of the second donkey, numerous small pieces of bark were found throughout the gastrointestinal tract. Tests on the stomach contents were positive for cyanide. A *Prunus virginiana* tree in the pasture was found to have been almost completely stripped of bark (Jackson, 1995).

Clinical signs

The onset of poisoning following ingestion of plant material containing cyanogenic glycosides is very variable and may be rapid (1–2 hours) or delayed; animals can die within a few minutes of onset of clinical features (Knight and Walter, 2003) or several hours later, but in many cases sudden death is the presenting sign. Animals observed to develop clinical effects may have ataxia, frothing at the mouth, dilated pupils, hyperventilation, dyspnoea, weakness, tremors, hypotension and collapse. In severe cases there may be coma, convulsions, lactic acidosis, cardiac arrhythmias and pulmonary oedema. Blood and mucous membranes are initially bright red (as a result of the oxygen saturation of haemoglobin); however, cyanosis (caused by tissue hypoxia) is observed in the terminal stage.

Treatment

Treatment is supportive. Antidotal therapy involves administration of sodium nitrite (10–20 mg/kg as a 20% solution) and sodium thiosulphate (30–40 mg/kg as a 20% solution intravenously, as a mixture of 1 ml of 20% sodium nitrate and 3 ml of 20% sodium thiosulphate given as 4 ml/45 kg body weight; Radke, 2022), where these are available. The dose of sodium thiosulphate can be repeated if required but only one dose of sodium nitrite should be given because of the risk of producing a high concentration of methaemoglobinaemia and exacerbating tissue hypoxia.

Sodium nitrite acts by converting haemoglobin to methaemoglobin for which cyanide has a high affinity; inert cyanmethaemoglobin is produced. Small doses of cyanide are converted to thiocyanate by an enzymatic reaction catalysed by rhodanese, an enzyme widely distributed in body tissues, particularly the liver. The rhodanese system can detoxify large amounts of cyanide but cannot respond quickly enough to prevent death. Sodium thiosulphate increases this reaction and acts by combining with cyanide in the presence of rhodanese to form the relatively non-toxic sodium thiocyanate (Knight and Walter, 2003).

Oak

Quercus (oak) species contain tannins and gallotannins, particularly in the buds and immature acorns. Toxicity is not reduced by drying or freezing. Tannins denature proteins and can damage the gastrointestinal tract, impairing digestion and possibly increasing absorption of toxic compounds. This may lead to increased vascular permeability and subsequent fluid loss. Absorbed tannins are metabolised to toxic components which results in tissue damage at the sites of highest concentration (such as in the kidney).

Poisoning usually occurs in the spring from eating the buds and young leaves, or in the autumn from ingestion of the acorns. Most cases of oak poisoning are reported in cattle but there have been cases in horses, often following a very hot, dry summer (Broughton, 1976; Daniels, 1976; Wharmby, 1976; Warren and Vaughan, 1985; Smith et al, 2015). Heavy rainfall and high winds may also be contributing factors. Although it is normal for animals, particularly horses, to eat acorns the reason why some cases result in poisoning remains unclear. Occasional cases are reported in donkeys; one donkey presented a day after ingestion of acorns with salivation, lethargy, inappetence and mild incoordination. He subsequently developed paralytic ileus and azotaemia but responded to supportive care and recovered in 4 days (Drozdzewska et al, 2018).

Clinical signs

Signs of poisoning may not occur until several days after ingestion. In severe cases, death may occur within 12–72 hours of onset of effects. Recovery can occur within 72 hours (Smith et al, 2015) but in some cases takes more than 2 weeks (Duncan, 1961).

Oak toxicity mainly causes gastrointestinal and renal signs in equids and reported signs include depression, abdominal discomfort, inappetence and constipation followed by diarrhoea. Faeces may be grey and contain acorn fragments and husks (Daniels, 1976). In more severe cases, there may be colic with gaseous distension, severe foul-smelling haemorrhagic diarrhoea, dehydration and hypovolaemia, incoordination, weakness, red or brown urine, head pressing, tachycardia and tachypnoea. Sweating can occur and the body temperature may be low (Warren and Vaughan, 1985; Smith et al, 2015) or high (Daniels, 1976; Anderson et al, 1983; Smith et al, 2015).

Mouth ulceration, inflammation of the pharynx and larynx, and dysphagia have also been reported in horses (Duncan, 1961; Warren and Vaughan, 1985). Coma and convulsions occur occasionally (Warren and Vaughan, 1985). Oedema of the throat and neck, ventral abdominal wall and legs has been reported (Duncan, 1961; Warren and Vaughan, 1985) and rupture of the stomach can occur (Wharmby, 1976).

Biochemical changes include levels of elevated urea, creatinine, liver enzymes, creatine kinase and lactate dehydrogenase, electrolyte disturbances, hyperglycaemia, hypoproteinaemia, metabolic acidosis, haemoglobinuria and glycosuria (Anderson et al, 1983; Smith et al, 2015; Drozdzewska et al, 2018).

Treatment

Treatment of oak toxicosis is supportive. Animals with mild effects often require only supplementation of diet with hay (Daniels, 1976). Renal function and fluid balance should be monitored. Laxatives, intravenous fluids, analgesia, blood transfusion products and colloids have been used in horses (Smith et al., 2015).

Cardiac glycosides

Cardiac glycosides are found in numerous plants including oleander (*Nerium oleander*, *Figure 4*), lily of the valley (*Convallaria majalis*) and foxglove (*Digitalis purpurea*), The glycosides found in plants, which are generally precursors (primary glycosides), undergo enzymatic hydrolysis when plant material is dried or damaged (for example when bitten and chewed) to give the active (or secondary) glycosides. The gastrointestinal absorption of many

primary glycosides is poor, compared with absorption of medicinal preparations (which are secondary glycosides), but poisoning can occur as a result of ingestion of plant material containing cardiac glycosides. Most cases in donkeys involve oleander (Smith et al, 2003; Renier et al, 2013).

Dried oleander is reportedly more palatable than fresh material (Butler et al, 2016). Cardiac glycosides inhibit the cellular membrane sodium-potassium adenosine triphosphatase (Na+K+ATPase) causing electrolye disturbance and resulting in changes in the electrical conducitvity of the heart. Although therapeutic doses of cardiac glycosides have an antiarrhythmic effect, larger amounts are proarrhythmic.

In an experimental study, donkeys given 10 or 20 mg/kg of powdered oleander leaves developed arrhythmias but survived. A dose of 30 mg/kg was fatal (Rezakhani and Maham, 1994). In an early study, a mule survived ingestion of 26g of fresh green leaves but died after ingesting 24g of dried leaves (Wilson, 1909).

In a review of 30 cases of oleander poisoning in equids (which included a small number of miniature donkeys) the mortality rate was 50% (10 died, 5 were euthanised). Survival was lower for animals with arrhythmias and higher for those with an increasing duration of hospitalisation (Renier et al, 2013).

Clinical signs

Sudden death is commonly reported after ingestion of plant material containing cardiac glycosides. Signs reported in donkeys and horses include abdominal discomfort and colic, depression, diarrhoea, ataxia, weakness, bradycardia or tachycardia, signs of ileus or gastrointestinal hypomotility, signs of decreased tissue perfusion (including weak pulse and slow capillary refill time), renal impairment, arrhythmias and cardiovascular collapse. Death can occur 12–36 hours after ingestion (Hughes et al, 2002).

Arrhythmias are typically ventricular in origin and commonly include ventricular premature contractions and ventricular tachycardia but atrioventricular (AV) block, AV dissociation, sinoatrial block, bundle–branch block, prolonged PR interval, ST deviation and ventricular fibrillation have also been reported (Wijnberg et al, 1999; Hughes et al, 2002; Smith et al, 2003; Durie et al, 2008; Renier et al, 2013).

Laboratory findings include haemoconcentration, hyperkalaemia, hyperglycaemia, acidosis, raised levels of creatine kinase, lactate, liver enzymes, urea and creatinine, and leucocytosis.

Treatment

Treatment of cardiac glycoside toxicity is supportive. Activated charcoal (*Box 3*, give a second dose 8 hours later) may be useful and analgesia may be required for abdominal discomfort. If possible, the levels of electrolytes, particularly potassium, should be checked. The electrocardiogram should be monitored, if possible. Rehydration may be required, but calcium-containing fluids should be avoided as elevated serum calcium concentrations can increase the effect of cardiac glycosides on the myocardium. Potassium should only be given if hyperkalaemia is absent.

Atropine can be used for AV block or bradycardia but in the horse there is the risk of gastrointestinal stasis. Lidocaine (0.25–0.5mg/kg IV slowly, then 20–50 mcg/kg/minute) has been used in the management of ventricular arrhythmias (Smith et al, 2003; Durie et al, 2008; Renier et al, 2013; Butler et al, 2016) and phenytoin (10-22 mg/kg orally every 12 hours or 10mg/kg IV, followed by 3 mg/kg IV every 12 hours) has been used in equines with cardiac glycoside-induced arrhythmias (Wijnberg et al, 1999; Smith et al, 2003; Durie et al, 2008). Digoxin antibody Fab fragments are an option but this drug is very expensive. The antibodies bind to the cardiac glycosides making the molecules unavailable for binding to the Na+K+ATPase pump on myocardial cells. The complex is then excreted in urine. In veterinary medicine it is recommended that 1 or 2 vials are given initially, and the effects observed (Gwaltney-Brant and Rumbeiha, 2002). More vials can be given if there is some clinical improvement. Digoxin antibody Fab fragments have been used in a horse with oleander poisoning reported to the VPIS. The horse died but this may have been for several reasons, including a suboptimal dose of antibodies.

*Figure 4. Oleander (*Nerium oleander*) contains cardiac glycosides which can be fatal if ingested.*

*Figure 5. Ragwort (*Jacobaea vulgaris*) contains pyrrolizidine alkaloids and chronic grazing can cause liver failure.*

Pyrrolizidine alkaloids (ragwort and rattlepods)

Numerous plants contain pyrrolizidine alkaloids, most importantly in the plant families *Asteraceae, Fabaceae* and *Boraginaceae*. The most commonly encountered plant in Europe is *Jacobaea vulgaris* (previously *Senecio jacobaea*, ragwort or tansy ragwort, ***Figure 5***) in the *Asteraceae* family. It is a common cause of poisoning in horses (Crews and Anderson, 2009; Vandenbroucke et al, 2010). This plant is not very palatable, but will be eaten if grazing is poor or if it is a contaminant of hay. Plants that are killed with herbicide also become more palatable.

Other pyrrolizidine alkaloid-containing plants are the cause of poisoning in other areas of the world, such as *Echium* species (Boraginaceae) in Australia and rattlepods (*Crotalaria* species, Fabaceae) in South America. In an experimental study in donkeys, dried whole *Crotalaria retusa* was mixed with grass and given at daily doses of 2.5g/kg, 5 g/kg and 10 g/kg. The donkey treated with 5 g/kg/day died 48 days later and the other were euthanised at 120 days. Clinical signs and pathology were similar to those observed in spontaneous cases of poisoning (Nobre et al, 2004).

The numerous pyrrolizidine alkaloids are metabolised to highly reactive pyrrole derivatives which react with cellular compounds, including proteins and nucleic acids, resulting in cytotoxic effects. Signs of poisoning present as a result of impaired liver function. Neurological effects occur as a result of elevated blood ammonia concentrations. The concentration of pyrrolizidine alkaloids in plants is very variable and species susceptibility is also variable. Horses, and presumably donkeys, as well as cattle are more susceptible to pyrrolizidine alkaloid toxicosis than goats and sheep.

Clinical effects

Signs of pyrrolizidine alkaloid toxicosis usually only occur after weeks, months or even years after exposure.

Onset of signs may occur abruptly in equids irrespective of the duration of exposure. Early signs are anorexia, weight loss and depression. There may also be diarrhoea or constipation, tenesmus, jaundice and signs suggestive of hepatic encephalopathy with head pressing, restlessness and aimless walking, apparent blindness and drowsiness. Gastric impaction and gastric rupture (Milne et al, 1990) and dyspnoea caused by laryngeal and/or pharyngeal paralysis (Pearson, 1991) have been reported as complications of ragwort poisoning in horses. Residual exercise intolerance has been reported in horses surviving pyrrolizidine alkaloid poisoning (Lessard et al, 1986).

In addition, some pyrrolizidine alkaloid-containing plants, particularly *Crotalaria* species, show a predominantly respiratory disease with severe tachypnoea and dyspnoea. This has been demonstrated experimentally in donkeys (Nobre et al, 2004; Pessoa et al, 2013).

*Figure 6. The 'Yesterday, today and tomorrow' shrub (*Brunfelsia *species) contains neurotoxins and is a concern in some countries as donkeys appear to find the plants particularly attractive.*

Treatment

Pyrrolizidine alkaloid toxicosis should be included in the differentials list for any donkey presenting with signs of subclinical liver disease, including weight loss. Biopsy findings are pathognomonic for pyrrolizidine alkaloid toxicosis.

Treatment is supportive but once signs have started, prognosis is generally poor. Management is the same as for animals with liver failure. Protein intake should be low to reduce the ammonia burden on the liver. Supplements and antioxidants have not shown consistent effects in animals with pyrrolizidine alkaloid poisoning.

Brunfelsia species

Brunfelsia is an evergreen shrub native to South and Central America, but now found elsewhere including Australia. *Brunfelsia* has characteristic strongly perfumed flowers that are initially purple but turn blue and then white as they mature over 3 days (***Figure 6***), and green to blackish-brown berries in the autumn.

Poisoning is uncommon in the UK, where it is grown as a conservatory plant. Numerous cases have been reported in dogs but poisoning in donkeys has occurred (Mello et al, 2010) and they appear to find the plant more palatable than ruminants (Mello et al, 2010). All parts of the plant are toxic, and several toxic compounds have been isolated from *Brunfelsia* species but the substance(s) responsible for the neurotoxic effects is unknown. It is thought to be a water-soluble stable solanine-like steroidal alkaloid. Brunfelsamidine (pyrrole-3-carboxamidine) is a convulsant that has been isolated from *Brunfelsia grandiflora* (Lloyd et al, 1985) and other potential toxic compounds include scopoletin and hopeanine (Spainhour et al, 1990).

Clinical signs

The clinical signs in donkeys intoxicated with *Brunfelsia* include diarrhoea, sweating, nystagmus, hypersalivation, bruxism, neurological signs (circling, ataxia, convulsions and paddling) and lateral recumbency (Mello et al, 2018). Death may occur if animals are not removed from areas invaded by the plant (Mello et al, 2010). Most cases in donkeys occur in December to March (in the southern hemisphere) and usually involve ingestion of leaves and flowers.

An experimental study in South America demonstrated differing toxic risks over the seasons. Leaves of *Brunfelsia uniflora* collected at the start or at the end of the rainy season, were administered in single doses of 5–20 g/kg to three donkeys. Two donkeys were

given leaves (5 or 10 g/kg) collected in November at the start of the rainy season, when the plant was flowering. The donkey given 5g/kg developed mild diarrhoea and had recovered by 24 hours. The one given 10 g/kg developed diarrhoea at one hour, then ataxia at 3.25 hours followed by convulsions at 14 hours. It was standing by 19 hours and eating again after 2 days and recovered. In contrast, a donkey given 20g/kg leaves collected in April after flowering, at the end of the rainy season, did not show any clinical signs (Mello et al, 2018).

Treatment

Treatment of *Brunfelsia* toxicosis in donkeys is supportive. Animals should be removed from the source. A calm, quiet environment may be helpful, and handling should be minimised. Rehydration may be required, and sedatives and anticonvulsants should be given as needed.

Metaldehyde

Metaldehyde has long been a common ingredient of molluscicide preparations, but the outdoor use of metaldehyde slug baits was banned in the UK from 31 March 2022, in a move to protect wildlife and the environment (Department for the Environment, Food & Rural Affairs and Health and Safety Executive 2020). It is likely to still be available in bulk quantities on farmland or small holdings, so cases are likely to continue. Cases of metaldehyde poisoning have been reported in donkeys (Blackett and Bates, 2017). The mechanism of metaldehyde toxicosis is not clearly understood, but it may be related to a decrease in the concentrations of the inhibitory neurotransmitters gamma-aminobutyric acid (GABA), noradrenaline and 5-hydroxytryptamine (Homeida and Cooke, 1982a; 1982b).

Clinical signs

Onset of signs after metaldehyde ingestion may be very rapid, often within 15–60 minutes, but can be up to 3 hours. In severe cases, death can occur within a few hours.

Incoordination, agitation, irritability, anxiety, hyperaesthesia, hyperpnoea, tachycardia, hypersalivation, pyrexia, sweating, diarrhoea (may be blue-green in colour as products are often dyed), nystagmus and apparent blindness have been reported. In severe cases there can also be muscle spasm, twitching and tremors leading to opisthotonus and continuous convulsions. Death is usually a result of respiratory failure. In animals that recover, no sequelae have been reported (Plumlee, 2001).

In a review of 18 VPIS cases of metaldehyde exposure in equines, the most common clinical signs were ataxia, convulsions, excitability, hyperaesthesia and muscle fasciculation/spasms/twitching. Overall, one animal remained asymptomatic, two animals were found dead, two died, three were euthanised and the remainder recovered. This case series included an incident involving three donkeys (about 200 kg) that had ingested an unknown amount of 6% metaldehyde bait. One was found dead, one died and the third was euthanised (Blackett and Bates, 2017).

In an experimental study an aged donkey (250 kg) was given 360 mg/kg of metaldehyde. Fifteen minutes later she had signs of mild colic, then developed a tremor an hour later. She had diarrhoea which by 2.5 hours was profuse and was sweating. By 8 hours there was tremor in all muscles and she later had incoordination with muscle tremor, fast shallow breathing and weak pulse. She deteriorated and died 15 hours after ingestion (Egyed and Brisk, 1966).

Treatment

There is no specific antidote for metaldehyde poisoning and treatment is symptomatic and supportive. A laxative or activated charcoal given by stomach tube may help delay absorption if given soon after ingestion (Miller, 1972), but administration may be difficult in an animal with tremors or convulsions.

The mainstay of treatment is the control of muscle tremors and convulsions. Diazepam may be given as first-line treatment, but may not control convulsions. Xylazine has been used in horses to reduce neurological signs and for sedation, but may not control convulsions (Plumlee, 2001). In severe cases, barbiturates or general anaesthesia may be required. Sedation should be allowed to wear off periodically to allow re-evaluation of the animal's clinical condition. Further dosing may be given if required. Prolonged tremors or seizures that cause excessive muscle activity can result in myoglobinuria and secondary renal complications, so intravenous fluids can help protect renal function (Dolder, 2003). Cooling measures may be required if increased muscle activity has resulted in pyrexia.

Anticoagulant rodenticides

Anticoagulant rodenticides such as difenacoum, brodifacoum, coumatetralyl, bromadiolone diphacinone, flocoumafen and difethialone are found in many preparations designed for the control of infestations of rats and mice. They inhibit hepatic vitamin K1 epoxide-reductase, the enzyme responsible for conversion of vitamin K1 epoxide to vitamin K1. This results in gradual depletion of the body stores of vitamin K1 needed to convert precursor coagulation proteins to their activated forms. There is a reduction in factors II (prothrombin), VII, IX and X and therefore inhibition of prothrombin synthesis within the liver. Once vitamin K1 and the clotting factors have been depleted, bleeding occurs, hence there is a lag of several days between ingestion and onset of signs.

Anticoagulant rodenticides are commonly used on farming and agricultural land and may be readily accessible to equids, but there are few published reports of anticoagulant rodenticide poisoning in horses, and they commonly involve brodifacoum (McConnico et al, 1997; Ayala et al, 2007; Zakian et al, 2019). A few cases in donkeys have been reported to the VPIS but none developed signs of toxicosis (VPIS case data). In one case, a 130kg pony died after eating an estimated 2 kg of 0.005% bait (so 0.77 mg/kg of bromadiolone or 15.4g/kg of bait) over an unknown period (Ayala et al, 2007). In another case, ingestion of approximately 4kg of 0.005% bait between two horses resulted in prolonged prothrombin time (PT), haematoma after venepuncture and epistaxis after nasogastric administration of mineral oil in one of the horses. They were treated with activated charcoal and vitamin K1 and both recovered (McConnico et al, 1997).

In an experimental study, six horses were given brodifacoum bait 0.125 mg/kg. By day 4, four of the horses were somnolent and anorexic and on day 7, all had weight loss which resolved by day 14. Only one horse required vitamin K1; it was severely depressed, pale

and anaemic, and received vitamin K1 on days 8, 9 and 10 with rapid improvement in appetite and demeanour. Laboratory findings in the horses included decreased haematocrit from day 8 to day 14 and decreased haemoglobin and red blood cells from day 6 to day 14. Significant elevation in the prothrombin time and activated partial thromboplastin time were observed from days 4 to 8. In four horses, clotting normalised by day 12 and in the remaining two by day 23. The maximum brodifacoum concentration occurred 2–3 hours after dosing and was detectable for 4–9 days (Boermans et al, 1991).

Clinical signs

Clinical effects are typically seen within several days of exposure (usually 3–5 days in dogs), but may be delayed for up to 7 days (DeClementi and Sobczak, 2012) and clotting parameters become prolonged before the onset of clinical signs.

Clinical signs are caused by coagulopathy and any type of bleeding may occur (such as gastrointestinal, pulmonary, brain). External bleeding is not always apparent, and internal bleeding is more common. As a result, clinical signs are variable. Initial signs may be non-specific with lethargy, weakness, anorexia, colic and pale mucous membranes. There is increased prothrombin time, activated partial thromboplastin and activated clotting time.

A pregnant 300kg Arabian mare that presented with signs of bleeding 54 hours after ingestion of a brodifacoum bait (0.005%), that had accidentally been mixed with her feed, aborted her 7-month old fetus. She recovered with vitamin K1 therapy and supportive care (Zakian et al, 2019).

Treatment

If ingestion was recent and the quantity ingested was large, a stomach tube can be passed to administer activated charcoal and a laxative. There is risk of epistaxis even in the absence of coagulopathy so placement of the tube must be done very carefully. This is not recommended in any animal with active bleeding owing to the risk of haemorrhage.

In equids, both the prothrombin time and the activated partial thromboplastin should be checked as there are reports of a prolonged activated partial thromboplastin with a normal prothrombin time in horses after ingestion of an anticoagulant rodenticide (Boermans et al, 1991; McConnico et al, 1997). The prothrombin time and activated partial thromboplastin should be checked daily for 2–4 days after ingestion (McConnico et al, 1997), starting 24–36 hours after ingestion. If these parameters are prolonged, vitamin K1 should be given at a dose of 2.5 mg/kg twice daily (subcutaneously or intramuscularly for up to 3 days, then switch to oral at the same dose. Although various regimens have been suggested it can be mixed with feed). Anticoagulant rodenticides have long half-lives so vitamin K1 therapy should be continued for 3–4 weeks, and clotting checked 2–3 days after cessation of therapy. If clotting remains abnormal another week of vitamin K1 should be given followed by repeat assessment of prothrombin time and activated partial thromboplastin.

Conclusions

Although much of the information on poisoning in donkeys is based on horses, cases have been reported in donkeys, both as clinical cases and experimental studies. Management in most cases is supportive but specific antidotes could be used in some cases, although these are generally prohibitively expensive or unavailable in veterinary medicine. Advice on possible clinical signs and management of poisoning cases can be obtained from a poisons information service, if required. EQ

KEY POINTS

- Donkeys are at risk of poisoning from toxic substances in their environment, such as plants and pesticides.
- The risk of poisoning can be reduced with preventative measures and appropriate care, such as preventing escape, secure storage of pesticides and ensuring that poisonous plants are not accessible in pastures.
- Signs of poisoning are likely to be similar to those seen in horses, but care should be taken when examining and treating donkeys because of differences in their behaviour, vital signs, laboratory parameters and therapeutics. Use donkey-specific resources for these.
- Seek specific advice from a poison information service, if required.

Conflicts of interest

The author has no conflicts of interest to declare.

References

Alden CL, Fosnaugh CJ, Smith JB, Mohan R. Japanese yew poisoning of large domestic animals in the Midwest. J Am Vet Med Assoc. 1977;170(3):314-6

Anderson GA, Mount ME, Vrins AA, Ziemer EL. Fatal acorn poisoning in a horse: pathological findings and diagnostic considerations. J Am Vet Med Assoc. 1983;10:1105-1110

Archer DC, Sullivan RJE, Rickards K. Emergency management for donkeys and mules. Vet Clin North Am Equine Pract. 2021;37(2):495-513. https://doi.org/10.1016/j.cveq.2021.04.013

Ayala I, Rodriguez J, Martos N, Zilberschtein J, Ruiz I, Motas M. Fatal brodifacoum poisoning in a pony. Can Vet J. 2007;48:627-629

Bates N. Atypical myopathy. UK-Vet Equine. 2022;6(3):96-102. https://doi.org/10.12968/ukve.2022.6.3.96

Blackett T, Bates N. Metaldehyde ingestion in 18 domestic equines. Clin Toxicol. 2017;55(5):43

Boermans HJ, Johnstone I, Black WD, Murphy M. Clinical signs, laboratory changes and toxicokinetics of brodifacoum in a horse. Can J Vet Res. 1991;55:21-27

Broughton JE. Acorn poisoning. Vet Rec. 1976;99:403-404

Burden FA, Du Toit N, Hazell-Smith E, Trawford AF. Hyperlipemia in a population of aged donkeys: description, prevalence, and potential risk factors. J Vet Intern Med. 2011;25(6):1420-5. https:/doi.org/10.1111/j.1939-1676.2011.00798.x

Burden F, Thiemann. A. Donkeys are different. J Equine Vet Sci. 2015;35:376–382 https://doi.org/10.1016/j.jevs.2015.03.005

Butler J, Khan S, Scarzella G. Fatal oleander toxicosis in two miniature horses. J Am Anim Hosp Assoc. 2016;52(6):398-402. https://doi.org/10.5326/JAAHA-MS-6433

Crews C, Anderson WA. Detection of ragwort alkaloids in toxic hay by liquid chromatography/time-of-flight mass spectrometry. Vet Rec. 2009;165(19):568-9. https://doi.org/10.1136/vr.165.19.568

Daniels MG. Acorn poisoning. Vet Rec. 1976;99:465-466

DeClementi C, Sobczak BR. Common rodenticide toxicoses in small animals. Vet Clin North Am Small Anim Pract. 2012;42(2):349-60. https://doi.org/10.1016/j.cvsm.2018.06.006

Department for Environment, Food & Rural Affairs (DEFRA), Health and Safety Executive. Press release. Outdoor use of metaldehyde to be banned to protect wildlife. Available from https://www.gov.uk/government/news/outdoor-use-of-metaldehyde-to-be-banned-to-protect-wildlife#:~:text=The%20outdoor%20use%20of%20metaldehyde,Minister%20Victoria%20Prentis%20announced%20today (accessed 30 September 2022)

Dolder LK. Metaldehyde toxicosis. Toxicology Brief. 2003:213-215

Drozdzewska K, Potocnik E, Schwarz BC. Suspected acorn poisoning in a donkey – a case report. Wiener Tierärztliche Monatsschrift. 2018;105(9/10):221-225. https://doi.org/10.1111/evj.12306

Duncan CS. Oak leaf poisoning in two horses. Cornell Vet. 1961;51:159-62

Durham A. Seasonal pasture myopathy: update on current threat. Vet Times. 2015;45(46):26-27
Durie I, van Loon G, De Clercq D, Deprez P. Nerium oleander intoxication in horses; 3 cases. Presented at the proceedings of the 47th British Equine Veterinary Association Congress, Liverpool, 2008
Egyed MN, Brisk YL. Metaldehyde poisoning in farm animals. Vet Rec. 1966;78:753-754
Fabius LS, Westermann CM. Evidence-based therapy for atypical myopathy in horses. Equine Vet Edu. 2018;30(11):616-622. https://doi.org/10.1111/eve.12734
Finno CJ, Valberg SJ, Wünschmann A, Murphy MJ. Seasonal pasture myopathy in horses in the midwestern United States: 14 cases (1998-2005). J Am Vet Med Assoc. 2006;229(7):1134-41
Gwaltney-Brant SM, Rumbeiha WK. Newer antidotal therapies. Vet Clin North Am Small Anim Pract. 2002;32(2):323-339
Haines A, Goliszek J. Donkey and mule behaviour for the veterinary team. UK-Vet Equine. 2019;3(1):27-32. https://doi.org/10.12968/ukve.2019.3.1.27
Hare WR. Yew (*Taxus* spp) poisoning in domestic animals. In: Toxic Plants and Other Natural Toxicants.Garland T, Barr AC (eds). CAB International, 1998; 78-80
Homeida AM, Cooke RG. Pharmacological aspects of metaldehyde poisoning in mice. J Vet Pharmacol Ther. 1982a;5(1):77–81
Homeida AM, Cooke RG. Anti-convulsant activity of diazepam and clonidine on metaldehyde-induced seizures in mice: effects on brain gamma-amino butyric acid concentrations and monoamine oxidase activity. J Vet Pharmacol Ther. 1982b;5(3):187-90
Hughes KJ, Dart AJ, Hodgson DR. Suspected Nerium oleander (Oleander) poisoning in a horse. Aust Vet J. 2002;80(7):412-5
Jackson T. Cyanide poisoning in two donkeys. Vet Hum Toxicol. 1995;37(6):567-8
Knight AP, Walter RG. Plants causing sudden death. In: A Guide to Plant Poisoning of Animals in North America. Jackson (WY): Teton NewMedia; 2003
Lessard P, Wilson WD, Olander HJ, Rogers QR, Mendel VE. Clinicopathologic study of horses surviving pyrrolizidine alkaloid (Senecio vulgaris) toxicosis. Am J Vet Res. 1986;47(8):1776-80
Lloyd HA, Fales HM, Goldman ME, Jerina DM, Plowman T, Schultes RE. Brunfelsamidine: a novel convulsant from the medicinal plant Brunfelsia grandiflora. Tetrahedron Lett. 1985;26:2623-2624
Lowe JE Hintz HF, Schryver HF, Kingsbury JM. *Taxus cuspidata* (Japanese yew) poisoning in horses. Cornell Vet. 1970;60(1):36-39
McConnico RS, Copedge K, Bischoff KL. Brodifacoum toxicosis in two horses. J Am Vet Med Assoc. 1997;211(7):882–6
McKenzie RK, Hill FI, Habyarimana JA, Boemer F, Votion DM. Detection of hypoglycin A in the seeds of sycamore (*Acer pseudoplatanus*) and box elder (*A. negundo*) in New Zealand; the toxin associated with cases of equine atypical myopathy. N Z Vet J. 2016;64(3):182-7. https://doi.org/10.1080/00480169.2015.112312
Mello GWS, Oliveira DM, Carvalho CJS, Pires LV, Costa FAL, Riet-Correa F, Silva SMM. Toxic plants for ruminants and equidae in Northern Piauí. Pesquisa Veterinária Brasileira. 2010;30(1):1-9. https://doi.org/10.1590/S0100-736X2010000100001
Mello GW, Riet-Correa F, Batista MC, Carvalho CJ, Dias AC, Franklin FL, Silva SM, Dias A. Poisoning by Brunfelsia uniflora in sheep and donkeys. J Vet Diagn Invest. 2018;30(3):476-478. https://doi.org/10.1177/1040638718757581
Miller RM. Metaldehyde poisoning in horses (two case reports). Vet Med Small Anim Clin. 1972;7(10):1141
Milne EM, Pogson DM, Doxey DL. Secondary gastric impaction associated with ragwort poisoning in three ponies. Vet Rec. 1990;126(20):502–4
Nobre VMD, Riet-Correa F, Barbosa JM, Dantas AFM, Tabosa IM, Vasconcelos JS. Poisoning by *Crotalaria retusa* (Fabaceae) in equidae in the semiarid region of paraiba. Pesqui Vet Bras. 2004;24:132–143. https://doi.org/10.1590/S0100-736X2004000300004
Ogden L. *Taxus* (yews) - a highly toxic plant. Vet Hum Toxicol. 1988;30(6):563-4
Olmos G, McDonald G, Elphick F, Gregory NG, Burden FA. A case study to investigate how behaviour in donkeys changes through progression of disease. Proceedings of 45th Congress of the International Society for Applied Ethology. Indianapolis, USA, 2011. Available from https://www.thedonkeysanctuary.org.uk/research/taxonomy/term/160
Pearson EG. Liver failure attributable to pyrrolizidine alkaloid toxicosis and associated with inspiratory dyspnea in ponies: three cases (1982-1988). J Am Vet Med Assoc. 1991;198(9):1651-4.
Pessoa CR, Pessoa AF, Maia LA, Medeiros RM, Colegate SM, Barros SS. Pulmonary and hepatic lesions caused by the dehydropyrrolizidine alkaloid-producing plants Crotalaria juncea and Crotalaria retusa in donkeys. Toxicon. 2013;71:113–120. https://doi.org/10.1016/j.toxicon.2013.05.007
Plumlee KH. Pesticide toxicosis in the horse. Vet Clin N Am Eq Pract. 2001;17(3):591-499
Radke S. Cyanide. In: Hovda L, Benson D, Poppenga RH (eds). Blackwell's Five-Minute Veterinary Consult Clinical Companion: Equine Toxicology. John Wiley and Sons, Hoboken (NJ); 2022:250-253
Renaud B, Kruse CJ, François AC et al. Acer pseudoplatanus: a potential risk of poisoning for several herbivore species. Toxins (Basel). 2022;14(8):512. https://doi.org/10.3390/toxins14080512
Rendle D. 'Atypical' myopathy - hypoglycin toxicity in horses. Livestock. 2016;21(3):188-193. https://doi.org/10.12968/live.2016.21.3.188
Renier AC, Kass PH, Magdesian KG, Madigan JE, Aleman M, Pusterla N. Oleander toxicosis in equids: 30 cases (1995-2010). J Am Vet Med Assoc. 2013;242(4):540-9. https://doi.org/10.2460/javma.242.4.540
Rezakhani A, Maham M (1994) Cardiac manifestations of oleander poisoning in cattle and donkeys. In: Colegate SM., Dorling PR., Allen JG, Huxtable CR, Panter KE (eds), Plant-associated Toxins: Agricultural, Phytochemical and Ecological Aspects. Wallingford: CAB International; 1994: 534–537
Smith PA, Aldridge BM, Kittleson MD. Oleander toxicosis in a donkey. J Vet Intern Med. 2003;17(1):111-4. https://doi.org/10.1892/0891-6640(2003)017<0111:otiad>2.3.co;2
Smith S, Naylor RJ, Knowles EJ, Mair TS, Cahalan SD, Fews D, Dunkel B. Suspected acorn toxicity in nine horses. Equine Vet J. 2015;47(5):568-72. https://doi.org/10.1111/evj.12306
Spainhour CB, Fiske RA, Flory W, Reagor JC. A toxicological investigation of the garden shrub Brunfelsia calcyina var. florbunda (yesterday-today-and-tomorrow) in three species. J Vet Diagn Invest. 1990;2:3–8
Tiwary AK, Puschner B, Kinde H, Tor ER. Diagnosis of Taxus (yew) poisoning in a horse. J Vet Diagn Invest. 2005;17(3):252-5. https://doi.org/10.1177/104063870501700307
Valberg S. Review of the discovery of the basis for a seasonal pasture myopathy/atypical myopathy. AAEP Proceedings. 2014:60:184-187
Vandenbroucke V, Van Pelt H, De Backer P, Croubels S. Animal poisonings in Belgium: a review of the past decade. Vlaams Diergeneeskundig Tijdschrift. 2010;79:251–268.
van Dierendonck MC, Burden FA, Rickards K, van Loon JPAM. Monitoring acute pain in donkeys with the Equine Utrecht University Scale for Donkeys Composite Pain Assessment (EQUUS-DONKEY-COMPASS) and the Equine Utrecht University Scale for Donkey Facial Assessment of Pain (EQUUS-DONKEY-FAP). Anim (Basel). 2020;10(2):354. https://doi.org/10.3390/ani10020354
van Galen G. Epidemiological and pathophysiological study of atypical myopathy in grazing horses. Master of Science Thesis, Faculty of Veterinary Medicine, University of Liège, Belgium, 2008. https://core.ac.uk/download/pdf/58881655.pdf
van Galen G, Amory H, Busschers E et al. European outbreak of atypical myopathy in the autumn 2009. J Vet Emerg Crit Care (San Antonio). 2010;20(5):528-32. https://doi.org/10.1111/j.1476-4431.2010.00574.x.
van Galen G, Marcillaud Pitel C, Saegerman C et al. European outbreaks of atypical myopathy in grazing equids (2006-2009): spatiotemporal distribution, history and clinical features. Equine Vet J. 2012a;44(5):614-20. https://doi.org/10.1111/j.2042-3306.2012a.00556.x
van Galen G, Saegerman C, Marcillaud Pitel C et al. European outbreaks of atypical myopathy in grazing horses (2006-2009): determination of indicators for risk and prognostic factors. Equine Vet J. 2012b;44(5):621-5.
van Galen G, Votion DM. Management of cases suffering from atypical myopathy: Interpretations of descriptive, epidemiological and pathophysiological findings. Part 1: First aid, cardiovascular, nutritional and digestive care. Equine Vet J. 2013;25(5):264-270. https://doi.org/10.1111/j.2042-3292.2012.00439.x
Votion DM. The story of equine atypical myopathy: a review from the beginning to a possible end. ISRN Vet Sci. 2012;2012:281018. https://doi/org/10.5402/2012/281018
Votion DM. Atypical myopathy: an update. In Pract. 2016;38:241–246. https://doi.org/10.1136/inp.i1859
Votion DM, Linden A, Saegerman C et al. History and clinical features of atypical myopathy in horses in Belgium (2000–2005). J Vet Intern Med. 2007;21(6):1380-91. https://doi.org/10.1892/07-053.1
Votion DM, van Galen G, Sweetman L et al. Identification of methylenecyclopropyl acetic acid in serum of European horses with atypical myopathy. Equine Vet J. 2014;46(2):146-9.
Warren CGB, Vaughan SM. Acorn poisoning. Vet Rec. 1985;116 (3):82.
Wharmby MJ. Acorn poisoning. Vet Rec. 1976;99:343.
Wilson CR, Sauer J, Hooser SB. Taxines: a review of the mechanism and toxicity of yew (*Taxus* spp.) alkaloids. Toxicon. 2001;39(2-3):175-85. https://doi/org/10.1016/s0041-0101(00)00146-x
Wilson FW. Oleander poisoning of livestock. University of Arizona Agricultural Experiment Station, Bulletin No. 29.
Wijnberg ID, van der Kolk JH, Hiddink EG. Use of phenytoin to treat digitalis-induced cardiac arrhythmias in a miniature Shetland pony. Vet Rec. 1999;144:259-261.
Zakian A, Mami S, Nouri M, Jalali SM, Tehrani-Sharif M. Brodifacoum toxicosis and abortion in an Arabian mare. Vet Res Forum. 2019;10(2):173-176. https://doi.org/10.30466/vrf.2018.85534.2115