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Megavertebrates

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For the purposes of this discussion, the term "megavertebrate" is taken to limit the scope of coverage on the basis of body weight, and includes the terrestrial plant-feeding mammals that typically attain an adult body mass in excess of one megagram (i.e., 1,000 kg). This demarcating criterion conventionally encompasses elephants (*Elephas maximus*, *Loxodonta africana*, *Loxodonta cyclotis*), rhinoceroses (*Ceratotherium simum*, *Diceros bicornis*, *Rhinoceros unicornis*, *Dicerorhinus sumatrensis*, *Rhinoceros sondiacus*) and hippopotamuses (*Hippopotamus amphibius*). Although giraffe (*Giraffa camelopardalis*) slip marginally into this category (Owen Smith, 1992), euthanasia of giraffe does not differ appreciably from other artiodactylids, and the hoofstock chapter of this document should be consulted for appropriate procedures.

Efficient euthanasia techniques that result in rapid loss of consciousness, cardiac and respiratory arrest and subsequent loss of brain function may be difficult to achieve in this group of mammals due to their massive size, intractable nature and unique anatomic features. The technique or combination of techniques selected will be determined by the species of animal, potential public exposure and risks to human safety, the chosen method of restraint prior to euthanasia, the skill of the personnel performing the euthanasia and other considerations. Acceptable methods include physical, chemical and adjunctive or combinations of these three.

CHEMICAL METHODS OF EUTHANASIA

Barbiturates

Barbiturates (pentobarbital or a pentobarbital combination) may be administered via intravenous catheter. In certain species, particularly the hippopotamus, superficial veins may be difficult to access. In addition, as a result of the extremely large volumes that are required to successfully euthanatize megavertebrates, it is important that subjects be anesthetized or otherwise immobilized prior to injection. Opioid agonists often used in conjunction with alpha-2 adrenergic agonists or other tranquilizers and administered by projectile dart or pole syringe, facilitate restraint and generally induce rapid immobilization in these species. Some practitioners advocate the use of massive overdoses of potent opioids to ensure profound sedation prior to euthanasia. It should be noted that while several veterinarians have attempted to euthanatize various megavertebrate species using massive doses of opioids, few have been successful (M. Bush, personal communication, 2001). Recommended doses found in the literature are usually adequate to immobilize the animal prior to euthanasia being performed and overdosing is not required. Doses required to immobilize or euthanatize megavertebrates require that sufficient volumes of drug are kept in stock.

Potassium Chloride

Potassium chloride (KCl) may be injected intravenously only in animals already under general anesthesia. In the zoo setting, this agent may be preferred to the use of barbiturates. The majority of necropsy facilities and rendering plants in the United States will no longer accept animals euthanatized using barbiturates. Chemical grade KCl is inexpensive and easily obtained. Cardiac arrest may be achieved following the rapid intravenous administration of approximately 44-66 mg KCl/kg body weight (R. Wack, 2004 personal communication; M. Atkinson, unpubl. data). More work is needed to determine species specific dosages. Potassium chloride can cause muscle spasms and violent animal movement unless administered to an animal under general anesthesia, or unless administered in combination with a barbiturate.

PHYSICAL METHODS OF EUTHANASIA

Gunshot

Gunshot to the head is the only appropriate physical technique for the euthanasia of the terrestrial megavertebrates. To achieve instant loss of consciousness by means of a gunshot, it is essential that the firearm be aimed such that the projectile enters the brain. To achieve this, differences in brain position and skull conformation between species must be accounted for, as well as energy requirement for skull bone and sinus penetration. Accurate targeting is described for the different species discussed. It should be noted that in fully conscious animals this technique is appropriate only in situations when a human life is in imminent danger and the animal must be killed. This technique requires significant skill and experience (in particular, the ability to shoot straight). A charging elephant, rhinoceros or hippopotamus may only present a 10-20 cm diameter target for an instant kill and an approximately 30 cm diameter target for a disabling hit that will turn the charge (T. O'Hara, personal communication 2003).

The advantage of gunshot euthanasia is instantaneous loss of consciousness (if the majority of the brain is destroyed). It might be the only practical method available in emergency situations. The disadvantages of gunshot euthanasia include danger to personnel and public, technical difficulty, aesthetically it is displeasing, and it destroys brain tissue.

The most appropriate weapon choice for megavertebrates is the 500 grain solid bullet of the .458 Winchester magnum or the .416 Rigby calibers. Smaller caliber weapons may be used to brain-shoot and kill an unconscious animal; however, in emergency situations where immediate stopping power is required, these smaller caliber weapons are not appropriate for use (Matunas 1993; Okimoto, 2001). A comprehensive discussion of weapon selection and appropriate responses in a typical zoological institution is published by Baker (1999).

Exsanguination

Exsanguination may be used as a secondary technique to ensure death in an otherwise unconscious animal.

ADJUNCTIVE METHODS OF EUTHANASIA

In many cases the use of lethal weapons is not a viable option and it may be difficult to restrain a fractious or dangerous animal for intravenous injection. By virtue of their size, megavertebrates may cause severe injury to bystanders prior to the sedative effects of immobilizing agents taking effect. In certain cases where physical methods cannot be employed, a neuromuscular blocker such as suxamethonium (succinylcholine chloride) may be administered provided the animal can be euthanatized with an appropriate technique as soon as control is achieved. It has been demonstrated that suxamethonium has a slow onset of effect in elephants following intramuscular injection (Pitts and Mitchell, 2002) with the onset of apnea occurring after approximately 5 min and death occurring after only approximately 30 min. Administration of a second technique that promptly results in unconsciousness and death must be administered as soon as safely possible, in order to conform to humane standards of euthanasia. The veterinarian administering this drug must be conscious of the potential danger involved; there is no antidote for suxamethonium and accidental self administration can result in death.

ELEPHANTS

Elephants are the largest living land mammals. African bull elephants may reach a height of 4.0 m at the shoulder and weigh 7000 kg, and Asian bulls may reach 3.5 m at the shoulder and weigh 5000 kg.

Chemical Methods of Euthanasia

Etorphine is the drug of choice for immobilizing elephants for full recumbent anesthesia. In addition, carfentanil as well as sedative/hypnotics such as xylazine also have been used successfully (Kock et al., 1993). In a controlled environment, an effective and humane method involves the administration of a recumbency-inducing dose of xylazine followed by the intravenous administration of KCl at 44-60 mg/kg body weight. Alternatively, euthanasia may be achieved using barbiturate overdose or by means of gunshot. Superficial veins used for venous access include the auricular, cephalic (proximal, medial foreleg) or saphenous (lower, medial hind leg) vessels. Because auscultation of the heart is frequently difficult in large elephants, cardiac monitoring and determination of death can be determined by the palpation or through ultrasound imaging of the superficial arteries. During an escape or in an otherwise threatening situation where humans are at risk, rapid recumbency can be achieved by darting the animal with a potent opioid (etorphine or carfentanil).

Physical Methods of Euthanasia

In zoos, sanctuaries and circuses, the potential exists for an animal escape that endangers human lives. In these rare situations the dangerous animal must be stopped immediately and gunshot may be used to bring the animal down. The brain lies on an axis drawn between the two external auditory meatus and is difficult to pinpoint with accuracy in a moving animal. The bony structure of the skull is "honey combed" and in a full grown adult bull may be as much as 300-400 mm thick in the frontal region. The brain cavity is small and situated low down in the back of the skull. Only a frontal shot that strikes the brain is sufficient to kill a charging elephant. To increase the chances of success, the animal should be within 25m from the shooter at the time the shot is taken and a follow-up brain shot is essential once the animal is down. Accuracy of placement can be determined by the action of the animal following the shot: a successful brain shot is characterized by the rear half of the body dropping first, followed by the head. In a situation where the head drops first or the whole body drops at the same time, it is likely that the bullet has missed the brain and a follow-up shot should be taken as soon as possible. A large bore round that strikes an animal in the skull but misses the brain will still provide 20-30 minutes of recumbency, during which time a fatal brain shot can be performed.

RHINOCEROS

Rhinoceros vary greatly in weight according to species (approximately 600 kg in the Sumatran rhino to >3000 kg in some male greater one-horned rhinoceros). They have short, stout limbs to support their massive weight and are characterized by one or a pair of horns located over the dorsal nasal area.

Chemical Methods of Euthanasia

Etorphine or carfentanil are the drugs of choice for immobilizing rhinoceroses for full recumbent anesthesia prior to euthanasia although other drugs in combination described in the literature may be used (Atkinson, 2002). In a controlled environment, an effective humane method of euthanasia involves the administration of a recumbency-inducing dose of etorphine followed by intravenous administration of KCl administered at 44 - 60 mg/kg. Alternatively, euthanasia may be achieved using barbiturate overdose or by means of gunshot. Superficial vessels used for venous access include the auricular or cephalic (proximal, medial foreleg) veins. In a moving animal, during an escape, or in an otherwise threatening situation, recumbency can be achieved by darting the animal with etorphine.

Physical Methods of Euthanasia

In certain closed situations (where safety of bystanders can be ensured), gunshot may be used to bring the animal down. The brain of the rhinoceros is small and, when the animal is viewed from the front, is generally well protected by the front horn. A charging rhino is almost impossible to kill by means of a brain shot and only a shot high on either shoulder will likely stop the charge. A fatal shot can then be administered with more precision. If the animal is not an immediate danger to bystanders, chemical immobilization (using a potent opioid agonist) should be performed prior to the administration of intravenous barbiturates or KCl.

If an animal has to be destroyed during transportation in a crate, it may be shot using a suitable weapon. The site of a rhinoceros brain may be visualized by extending a line from the base of each ear to the opposite eye. The point where these lines bisect indicates the location of the brain. If gunshot is not feasible, is undesirable or dangerous, 1 g of suxamethonium can be administered intramuscularly either by hand or by means of a dart (Rogers, 1993) prior to euthanasia being performed.

HIPPOPOTAMUS

The common hippopotamus has a large barrel-shaped body supported by relatively short, light limbs. Adults may reach 1.4m at the shoulder and weights range from 1000 to 3200 kg. They are difficult to restrain and handle due to their size and strength and if cornered will bite, trample or crush their perceived enemy. The thick skin with its slippery secretions and body conformation make it extremely difficult to move or handle an immobilized animal. The skull is pear-shaped and the orbits are high on the head in the posterior half of the skull. The mandible is disproportionately large with heavy canine teeth.

Chemical Methods of Euthanasia

The potent opioids, etorphine or carfentanil, are the drugs of choice for immobilizing a hippopotamus for full recumbent anesthesia prior to euthanasia although other drugs in combination described in the literature may be used (Loomis et al., 1999; Morris et al., 2001). Hippos will enter the water when they are alarmed and therefore immobilization must be carried out in such a manner that accidental drowning can be avoided. In a controlled environment, an effective humane method of euthanasia involves the administration of a recumbency-inducing dose of etorphine followed by intravenous administration of KCl administered at 44 - 60 mg/kg. Hippos are very sensitive to the effects of potent opioids and fatal complications are frequently associated with higher doses of etorphine (up to 12mg). Some practitioners prefer the use of very high doses of etorphine (>20 mg) to ensure rapid recumbency and profound sedation allowing for reduced volumes of KCl for euthanasia (R. Wack personal communication, 2004).

Euthanasia may also be achieved using barbiturate overdose. Superficial veins used for venous access include the auricular or cephalic (proximal, medial foreleg) vessels. Ultrasound may be used to locate the superficial veins; however, successful catheterization is problematic due to the thin-walled nature and likely collapse of these vessels. For the massive size of the skull, the braincase is surprisingly small.

Physical Methods of Euthanasia

An emergency head shot in a hippopotamus should only be taken low between the eyes, directed up through the nasal cavity or at the base of the ear. Because auscultation of the heart is frequently impossible in hippos, cardiac monitoring and determination of death can be determined by the palpation or ultrasound of the superficial arteries.

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