Australian
VETERINARY
JOURNAL

CLINICAL SECTION

A review of drugs and techniques used for sedation and anaesthesia in captive rhinoceros species

TJ PORTAS
Western Plains Zoo, PO Box 831, Dubbo, New South Wales 2830

Captive rhinoceros species are most frequently sedated and/or anaesthetised with the potent opioid, etorphine hydrochloride in combination with an alpha-2 adrenoreceptor agonist or the butyrophenone, azaperone. Carfentanil citrate based combinations have also been used to a lesser extent. In recent years butorphanol tartrate based combinations have been used with good success to induce neuroleptanalgesia. Sedation and anaesthesia are complicated by the large size of all rhinoceros species and their sensitivity to potent opioids. Potential complications include respiratory depression, hypoxaemia, hypertension, pulmonary shunting and ventilation/perfusion mismatch. The pharmacology of the principal drugs used for sedating/anaesthetising rhinoceros is reviewed. Techniques for sedating/anaesthetising the various species and potential complications associated with chemical restraint are discussed.
Aust Vet J 2004;82:542-549

There are five extant species of rhinoceros and four of these are currently maintained in captivity. The white rhinoceros (*Ceratotherium simum*), the black rhinoceros (*Diceros bicornis*) and the greater one horned rhinoceros (*Rhinoceros unicornis*) are relatively commonly maintained in captivity, while the captive population of the Sumatran rhinoceros (*Dicerorhinus sumatrensis*) is currently limited to eight individuals (ZZ Zainuddin, personal communication). The Javan rhinoceros (*Rhinoceros sondaicus*) is not maintained in captivity. Restraint is frequently necessary for routine medical treatment and for diagnostic and surgical procedures in captive rhinoceros. Tractable individuals may be conditioned to restraint chutes for minor procedures such as venipuncture and reproductive examinations. For more invasive procedures and in situations where restraint chutes or resources for intensive conditioning are unavailable, sedation and/or anaesthesia is required.

Protocols for anaesthesia and sedation usually involve the use of an opioid in combination with either an alpha-2 adrenoreceptor agonist, such as xylazine[1-3] or detomidine,[3, 4-6] or the butyrophenone, azaperone.[7-9] Restraint varying from standing sedation to surgical anaesthesia can be achieved with these combinations. Three neuroleptic drugs, azaperone, perphenazine enanthate and zuclopenthixol acetate, have been used to produce a degree of mild sedation during transport and following release into new environments in the black[1, 9] and white rhinoceros.[10, 11] Anaesthesia in these species is complicated by their large size and sensitivity to opioid drugs. Complications include respiratory depression,[1, 2] hypoxaemia,[12, 13] hypertension,[14] pulmonary shunting and ventilation/perfusion mismatching.[7, 13] Renarcotisation is a potential serious complication in the white rhinoceros following immobilisation with etorphine or carfentanil.[7] Substantial planning should precede sedation/anaesthesia in captive rhinoceros to minimise the adverse effects of any potential complications. This paper reviews the pharmacology of the principal drugs used and details important clinical considerations when utilising chemical restraint in captive rhinoceros.

Drug pharmacology

Opioids

Three opioids are currently used as the principal drugs for chemical restraint of captive rhinoceros species: etorphine hydrochloride, carfentanil citrate and butorphanol tartrate. Etorphine hydrochloride and carfentanil citrate are rapid acting, extremely potent and can be rapidly fatal in humans following inadvertent exposure to even small volumes. These drugs should therefore only be used by experienced personnel in the presence of another person trained to administer an antagonist and provide emergency first aid.

Etorphine hydrochloride — Etorphine hydrochloride is a semi-synthetic thebaine derivative that has an analgesic potency 1000 to 3000 times that of morphine. Etorphine is lipophilic and has a greater affinity for opioid receptors compared to morphine.[15] Etorphine is

Table 1. Anaesthetic, sedative and neuroleptic durgs used in captive rhinoceros.[4-8,12,18,20,21,24,26,29]

Species	Recumbency	Standing restraint	Neuroleptic agents
White			
Juvenile	0.5 mg etorphine + 10mg azaperone	15 - 25 mg butorphanol	50-100 mg azaperone
Sub-adult	1.8 - 2.2 mg etorphine + 15 - 25 mg azaperone[a]	0.5 - 1 mg etorphine[a]	60 - 150 mg azaperone 100 - 200 mg zuclopenthixol acetate
Adult	2 - 3 mg etorphine + 20 - 40 mg azaperone[a] 70 mg butorphanol + 100 mg azaperone 1.2 mg carfentanil	0.8 - 1.5 mg etorphine[a] 50 - 70 mg butorphanol + 100 mg azaperone	50 - 300 mg azaperone 100 - 200 mg zuclopenthixol acetate 100 - 300 mg perphenazine enanthate
Black			
Juvenile	0.9 mg carfentanil	30 mg butorphanol	
Sub-adult	2 -2.5 mg + 8 - 10 mg detomidine[a]	0.5 - 1.25 mg etorphine + 2 - 5 mg acepromazine	100 - 150 mg azaperone 50 - 100 mg zuclopenthixol acetate
Adult	2.5 - 3 mg etorphine + 10 mg detomidine[a] 2.5 - 3 mg etorphine + 60 mg azaperone[a] 300 µg/kg butorphanol + 60 µg/kg detomidine 1-1.5 mg carfentanil	1.25 - 1.5 mg etorphine + 5 - 6 mg acepromazine 2 - 2.5 mg etorphine + 10 mg detomidine + 15 mg butorphanol[a]	100 - 200 mg azaperone 100 - 200 mg zuclopenthixol acetate 100 - 200 mg perphenazine enanthate
Greater one horned			
Juvenile	0.5 - 1 mg etorphine + 5 mg acepromazine		
Sub-adult	2.0 mg etorphine + 10 mg acepromazine 0.5 - 0.8 mg etorphine = 8 - 10 mg detomidine		
Adult	2.5 mg etorphine + 10 mg acepromazine 3.5 - 3.8 mg etorphine + 14 mg detomidine + 400 mg ketamine	0.5 - 1.5 mg etorphine	
Sumatran			
Adult	300 µg/kg butorphanol + 60 µg/kg detomidine	0.98 - 1.23 mg etorphine + 4 - 5 mg acepromazine 25 mg butorphanol 150 µg/kg butorphanol + 30 µg/kg detomidine	

[a]Doses derived from those in current use by author

frequently combined with sedatives or neuroleptic drugs to produce anaesthesia in ungulates. Onset of effect occurs within 2 to 12 minutes of administration and the peak effect occurs at 20 to 30 minutes. Recovery is prolonged without the administration of specific antagonists.[15] Hypertension secondary to increased cardiac output and increased peripheral vascular resistance is common and may also relate to increased sympathetic stimulation in animals maintained at a light plane of anaesthesia.[7] Respiratory depression is common in rhino following the administration of etorphine.[1, 7, 13] This depression is dose dependent and may be compounded by rigidity of the thoracic musculature, which adversely affects the adequacy of respiratory excursions. This may also confound attempts to ventilate the animal. Muscular rigidity and tremors also place the animal at greater risk of hyperthermia and may make monitoring of physiological variables such as heart and respiratory rates difficult. A reduction in gastrointestinal motility occurs, as may mydriasis and hypersalivation.[15] Renarcotisation can occur secondary to enterohepatic recycling or from redistribution of drug deposited in fat.[7] Signs of renarcotisation may include head pressing, sedation and recumbency. White rhino are especially prone to renarcotisation and opioid anaesthesia should be reversed with naltrexone. Diprenorphine will not antagonise the effects of etorphine completely in white rhino and animals remain partially narcotised for up to 8 hours following the administration of diprenorphine.[3, 11]

Carfentanil citrate — Carfentanil citrate is a synthetic phenylpiperidine with 10,000 times the analgesic potency of morphine. It has similar pharmacological effects to etorphine but is more rapidly acting, with its maximum effect seen within 2 to 10 minutes of administration.[15] Carfentanil has a longer duration of action than etorphine. Immobilisation is achieved more quickly and respiratory depression is less evident than with etorphine. Regardless of the antagonist used recovery times are generally greater than 4 minutes for carfentanil.[16, 17] Carfentanil has been used for the immobilisation of free ranging white rhino,[7, 11] free ranging greater one horned rhino[18] and in both captive black[19] and white rhinoceros.[17]

Butorphanol tartrate — Butorphanol tartrate is a synthetic opioid with agonistic-antagonistic properties. It has three to five times the potency of morphine with less marked respiratory and cardiovascular effects.[8] Respiratory rate and pulse oximetry values in rhino are generally better maintained than with etorphine based combinations (personal unpublished data). In recent years butorphanol has been used alone for sedation[20] or in combination with azaperone for anaesthesia in white rhinoceros[8] and alone for sedation[21] or in combination with detomidine for anaesthesia in both Sumatran and black rhinoceros.[12]

Opioid antagonists

Antagonism of opioid anaesthesia is possible with a variety of drugs. Choice of drug will depend upon the species and level of antagonism required. Four drugs are either currently available in Australia or may be imported from overseas: naloxone hydrochloride, diprenorphine hydrochloride, naltrexone hydrochloride and nalorphine hydrobromide.

Diprenorphine hydrochloride — Diprenorphine hydrochloride has mixed opioid agonistic and antagonistic properties and is marketed as the reversal agent for etorphine.[15] Recovery following intravenous administration typically occurs within 30 to 90 seconds in rhinoceros.[7] White rhino remain partially narcotised following reversal of etorphine and carfentanil anaesthesia with diprenorphine.[15, 17] This can be used to good effect to provide sedation for a period of approximately 6 hours when transporting animals loaded under etorphine sedation, however the animals should be monitored closely to prevent recumbency or excessive head pressing (M Hofmeyr, personal communication). Renarcotisation has not been reported as a problem in other rhino species following diprenorphine antagonism of etorphine anaesthesia or sedation. Low doses of diprenorphine have been used to antagonise partially the effects of etorphine to facilitate loading of white rhino into crates, however the response is variable (M Hofmeyr, personal communication). Diprenorphine is typically administered at three times the immobilising dose of etorphine with two thirds of this administered intravenously and the remainder subcutaneously.[15]

Naloxone hydrochloride — Naloxone hydrochloride is a specific opioid antagonist with no known agonistic properties. It has a short half-life (as short as 30 minutes in some species) and if used alone for the reversal of etorphine and particularly carfentanil, renarcotisation is likely to occur.[15] This drug should only be used to antagonise butorphanol sedation in rhinoceros. It is currently being investigated at low doses for partial antagonism of carfentanil induced respiratory depression in other ungulate species[22] and this application maybe appropriate for rhinoceros species. Naloxone at 0.04 mg/kg has been recommended for antagonism of etorphine.[15]

Naltrexone hydrochloride — Naltrexone hydrochloride has no known agonistic properties and is considered the reversal agent of choice for carfentanil because of its relatively long half life (10 hours).[16] It is used at 100 mg per 1 mg of carfentanil[16] and at 20 mg per 1 mg of etorphine.[15] Because of the potential for renarcotisation, carfentanil anaesthesia in rhino should be reversed with naltrexone. In southern white rhino doses of 40 mg naltrexone per 1 mg etorphine appear to be necessary to prevent renarcotisation. Naltrexone may prevent complete narcotisation if anaesthesia is subsequently attempted within 24 hours of administration.[5] Half the reversal dose of naltrexone is typically administered intravenously and half the dose administered intramuscularly. Sudden arousal and short periods of excitement during recovery have been noted following the intravenous use of naltrexone.[7] Naltrexone has been associated with facial pruritus on multiple occasions in a single greater one horned rhinoceros.[4]

Nalorphine hydrobromide — Nalorphine hydrobromide has both agonistic and antagonistic properties. Nalorphine is rapid acting when given as an intravenous injection. It may enhance the respiratory depressant effects of non opioid drugs.[15] It may be used for the reversal of etorphine anaesthesia in rhinoceros but in white rhino, at least, it results in incomplete antagonism.[7, 15] Its principal use in rhino anaesthesia is to antagonise partially the effects of etorphine in recumbent animals.[7] Small doses (5 to 10 mg) administered intravenously will improve respiration and blood oxygenation and reduce hypertension.[1, 3, 7] The plane of anaesthesia will be lightened following the administration of nalorphine. By carefully titrating the dose of nalorphine administered, white and black rhino can be stimulated to stand, and, with the use of a rope positioned behind the posterior horn and another rope looped around a hind limb, walked in a controlled manner for distances up to 2 kilometres.[1, 7, 9] A total dose of 250 mg nalorphine per adult animal has been recommended for the reversal of etorphine based anaesthesia.[7]

Sedative drugs

Xylazine, detomidine and azaperone have been used in combination with opioids to provide neuroleptanalgesia in both captive and free ranging rhino. These drugs are combined with etorphine, carfentanil or butorphanol to provide muscle relaxation, smoother inductions and recoveries and to speed up induction times.[1-3]

Xylazine hydrochloride — Xylazine has sedative, analgesic and muscle relaxant properties that are mediated by central nervous system depression. Stimulation during induction may prevent optimum sedation. Side effects may include disruption of thermoregulation, bradycardia, profuse salivation and partial atrioventricular block.[15] Xylazine has been used extensively in combination with etorphine for anaesthesia of both white and black rhino in southern Africa.[1, 3] This drug has been used on its own to provide mild to moderate sedation in captive rhinoceros at doses of 0.25 to 0.5 mg/kg.[7] Yohimbine hydrochloride or atipamezole hydrochloride maybe used to reverse the effects of xylazine.[15]

Detomidine hydrochloride — Detomidine has a rapid onset of action (2 to 10 minutes) and is more potent than xylazine. Detomidine has potent sedative and analgesic effects.[15] Profuse salivation appears to be less of a problem than with xylazine. The initial period of hypertension is greater and longer lasting than with xylazine and this should be considered when using detomidine in combination with etorphine or carfentanil.[15] The rapid onset of action of detomidine makes this a useful drug in combination with opioids in species that are prone to excitement during induction. The use of detomidine in combination with etorphine has been reported in white rhino[3] and greater one horned rhino.[4, 5] It has also been used in combination with butorphanol in black rhino and Sumatran rhino.[12] Atipamezole maybe used to reverse the effects of detomidine.[15]

Short and long acting neuroleptic drugs

Azaperone, zuclopenthixol and perphenazine have been used to provide a degree of tranquillisation and in so doing reduce the level of mortality and morbidity associated with translocation of animals.[1,7,9] These neuroleptic agents, while valuable adjuncts to the successful transportation and settling in of rhinoceros, should not be used as substitutes for thorough planning, conditioning of animals, or the adherence to the highest standards during transportation of animals.

Azaperone — Azaperone is a butyrophenone frequently used as an opioid synergist for the chemical immobilisation of wildlife or on its own as a short acting neuroleptic agent.[7-9, 11] Initial effect is seen within 15 to 20 minutes and the drug's duration of effect is around 6 hours. In horses, in the experimental setting, there are minimal effects on arterial PaCO, PaO2 and pH. There is a reduction in PCV and haemoglobin concentration. Mean arterial blood pressure is reduced via a reduction in peripheral resistance and is accompanied by a slight increase in cardiac output.[23] Azaperone produces peripheral vasodilation and reduces the hypertensive effects of etorphine and may even counteract the respiratory depression caused by etorphine. Azaperone has been used in combination with etorphine extensively in recent years for chemical restraint of free ranging and confined black[9] and white

rhinoceros.[7, 8, 11] Azaperone in combination with butorphanol provides effective chemical restraint in captive white rhinoceros.[8] Used alone azaperone is an effective calming agent in rhinoceros providing short duration sedation of 4 to 6 hours, with an onset of effect within 15 to 20 minutes after intramuscular injection. Total doses of 60 mg per adult animal are usually sufficient to calm animals confined in crates. Deeper sedation can be achieved with total doses of 200 to 400 mg in adult animals, although animals will tend to become recumbent with these higher doses.

Zuclopenthixol acetate — Zuclopenthixol acetate has been used extensively during transportation, translocation and the subsequent adaptation period in both species of African rhinoceros.[7, 9] Onset of effect of this thioxanthene following intramuscular injection is 1 hour and duration of effect is usually in the order of 3 to 4 days. The recommended total dose of zuclopenthixol for adult black rhinoceros is 100 to 200 mg.[9] In the author's experience a total dose of 100 mg is sufficient to produce a noticeable calming effect in captive, adult, white rhinoceros.

Perphenazine enanthate — Perphenazine enanthate is a phenothiazine derivative contained in a sesame oil base. Onset of effect occurs within 12 hours and peak effect occurs at 2 to 3 days. The duration of action of this drug is around 7 to 10 days.[15] This drug has been used in both black and white rhinoceros. Good results have been obtained with perphenazine during the translocation of black rhinoceros,[1] however variable results have been obtained using this drug in white rhino, with some workers finding doses over 150 to 200 mg causing anorexia (M Hofmeyr, personal communication). Perphenazine is metabolised extensively in the liver and has been implicated as a possible contributing factor to the hepatopathy syndrome seen in translocated black rhinoceros. The recommended total dose for adult white and black rhino is 100 to 300 mg.[1, 9]

Other drugs

A number of other drugs have been used to facilitate muscle relaxation and provide balanced anaesthesia in rhino. Ketamine hydrochloride has been used to hasten the attainment of recumbency in white rhino,[24] and in combination with etorphine and detomidine, for anaesthesia in greater one horned rhino.[4] Intravenous boluses of ketamine should be administered with caution because of the potential for apnoea. The use of guaiphenesin has been reported in two rhino in combination with barbiturates to enhance muscle relaxation and facilitate intubation, and alone in another animal with little apparent effect.[13,25,26] The author has used midazolam hydrochloride (15 mg intravenously) to provide further muscle relaxation in adult white rhino anaesthetised with opioid based combinations and other workers have reported the use of 10 to 20 mg of midazolam to provide muscle relaxation in white rhino anaesthetised with etorphine based combinations (M Hofmeyr personal communication). While midazolam provides good muscle relaxation it should be used with caution as the benzodiazepines may enhance opioid induced respiratory depression. Hyaluronidase is an enzyme that facilitates absorption of anaesthetic drugs administered intramuscularly through its action upon hyaluronic acid, the intracellular cement of connective tissue.[15] Its use has been shown to reduce induction times in wild black[1] and white rhino.[3] Doses up to 7500 IU for this drug in combination with anaesthetic agents have been reported.[15] In the author's experience the addition of hyaluronidase can significantly reduce induction times, however results may be variable. Its use is probably not necessary in the captive situation, with the exception of the black rhino, in which rapid inductions are preferable to minimise the risk of injuries that maybe sustained during the excitement phase. Doxapram maybe used to improve the rate and depth of respiration in recumbent rhino, however when used alone it has little effect on blood oxygen saturation.[7] Doxapram is routinely used in combination with nalorphine to counteract respiratory depression in black and white rhino anaesthetised in the field. Intubation and maintenance of anaesthesia with isoflurane has been reported in the greater one horned, [26] black rhino[6] and white rhino.[25] Intubation can be difficult, particularly at lighter planes of anaesthesia and for routine procedures is probably not necessary. The author provides oxygen via nasal insufflation at a rate of 15 L/min in both standing and recumbent narcotised animals. Provision of equipment for intubation and ventilation in the event of an anaesthetic emergency should be routine when anaesthetising captive rhinoceros.

Preparation

Passive regurgitation of water has been reported to be a problem in white rhino that have consumed large volumes of water just prior to immobilisation.[7] In the captive situation where control of water intake is possible, denying the animal access to water for up to 12 hours prior to anaesthesia is a reasonable precaution. Full water troughs and wallows also represent drowning hazards for a

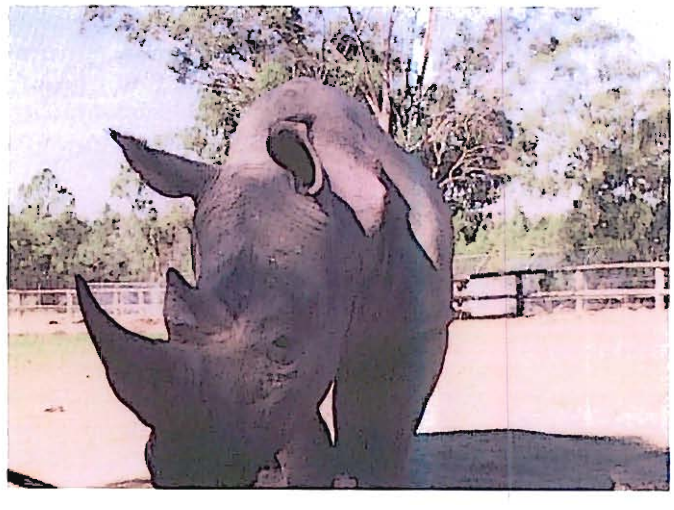

Figure 1. Abscesses frequently develop at the dart site in white rhino.

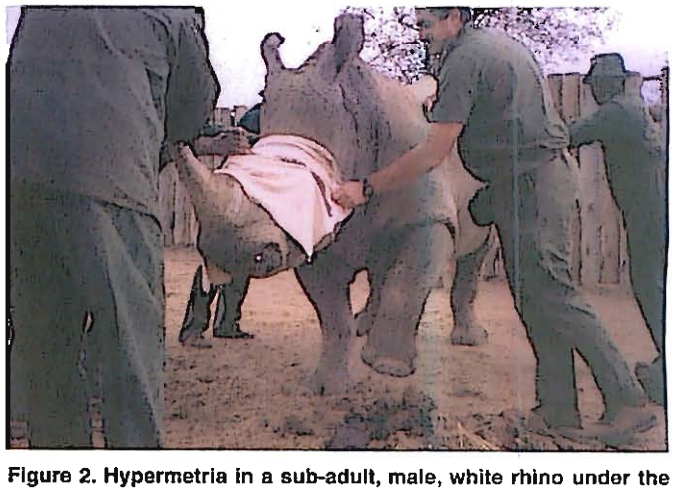

Figure 2. Hypermetria in a sub-adult, male, white rhino under the effect of etorphine and azaperone.

large species that is not easily manipulated when narcotised. Large numbers of free ranging black, white and greater one horned rhino have been anaesthetised for translocation without pre-anaesthetic fasting. Complications associated with this practice have not been reported, but in the captive situation fasting pre-anaesthesia is a reasonable precaution.

Careful consideration should be given to the area in which the animal is to be anaesthetised. Black rhino undergo an excitement phase during induction and yards should be free of obstacles. Horizontal bars can be problematic with partially narcotised animals showing a tendency to head press. In such situations the animal may rest the weight of its body on the horn, resulting in avulsion or fractures of the horn. The animal may also trap its head over or through horizontal bars prior to recumbency.

Restraint procedures should be avoided when ambient temperatures exceed 30°C, as hyperthermia is problematic in rhinoceros species following the administration of opioids.[24] Hyperthermia maybe particularly problematic in the black rhinoceros because of the tendency for these animals to pace during the induction of anaesthesia. Sufficient volumes of water should be available to cool the animal if its rectal temperature rises above 39°C.

An electric cattle prod is a useful tool to have on hand. Employed judiciously, electric prodders can be used to discourage semi-narcotised animals from head pressing in precarious situations or in stimulating animals to rise following the administration of small doses of nalorphine. Two soft cotton ropes 10 metres or more in length are useful for manipulating semi-narcotised or recumbent animals.

During long procedures myositis and/or neuropathy should be anticipated as complicating factors because of the large size of all rhino species. Careful positioning of padding in the form of water or air filled mattresses prior to or following recumbency should reduce these risks. An alternative approach in shorter procedures is to adjust the positioning of the recumbent animal every 20 minutes to avoid prolonged pressure on given areas. Care should be taken to minimise the period of time for which the animal is recumbent.

Figure 3. Opportunistic blood collection for plasma storage from the radial vein of an adult, female, black rhino. Note the catheter in the auricular vein, positioning of a pulse oximeter probe on the pinna and the use of copious volumes of water to cool the animal following excessive pacing during induction.

Clinical sedation/anaesthesia

Every effort should be made to ensure that the rhinoceros is calm before drug administration and subsequently during the induction. The well vascularised musculature of the nuchal hump is the preferred site for dart placement. The musculature of the hind limb or shoulder is also a suitable site for dart placement in the black,[1] white[3, 7] and Sumatran rhinoceros. The dart must be placed perpendicular to the skin to avoid subcutaneous drug deposition. Appropriate pressure settings should be utilised on projectors to ensure penetration of the animal's thick dermis. Robust needles 80 mm in length and 2 mm in diameter should be used.[7] Skin plugs are a potential problem when using open needles. Abscesses frequently develop at dart sites (Figure 1) and the treatment of dart wounds with intramammary antibiotic preparations has been advocated.[7]

Following the administration of etorphine in captive white rhino a fairly predictable sequence of events occurs. The animal will stand quietly and stare, the whites of the eye become prominent, there is extension of the neck with resultant elevation of the head and the rhino may develop side ways movements and hypermetria (Figure 2) prior to becoming laterally or sternally recumbent. Black rhino exhibit a pronounced excitement phase with pacing similar to that seen in a range of other ungulate species darted with etorphine and typically head press before becoming recumbent. Inductions with butorphanol and azaperone in white rhino are calm, with a gradual onset of sedation, development of a wide based stance, mild ataxia and incoordination preceding standing sedation or recumbency.[8]

In white rhino a blindfold can generally be placed shortly after the animal has become hypermetric. A white flag can be waved in front of the animal to test its response to stimulation. The rhino should be approached from behind or the side with caution. A blindfold is placed over the posterior horn, covering the eyes but not the nostrils.

During the induction phase, animals may lean against the walls of the enclosure, resting the full weight of their body upon the horn. This is to be avoided where possible and electric prodders may be judiciously used to correct this situation. The animal may be pulled down into sternal recumbency, which is preferred over lateral recumbency. Dog sitting is to be avoided because pressure on the musculature of the hind limbs in this position can lead to myositis with subsequent difficulties as the animal attempts to rise. Dog sitting occurs relatively frequently in white rhino during induction with etorphine based combinations.

Following recumbency or standing sedation intravenous access should be established by catheterisation of an auricular vein.

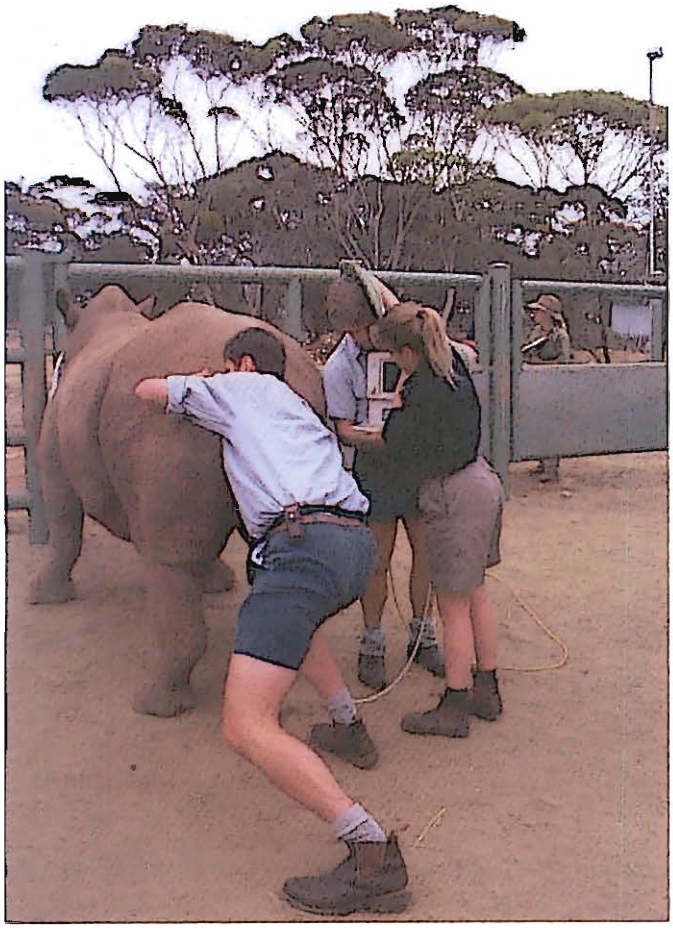

Figure 4. Standing sedation in an adult, female, white rhino to facilitate transrectal ultrasonography for pregnancy diagnosis.

Other sites for venous access in rhino include the cephalic or radial vein or their branches located on the medial aspect of the forelimb[27] (Figure 3). These vessels are relatively easy to locate in the black rhino and also are accessible in the white, greater one horned and Sumatran rhino. Use of a tourniquet facilitates catheterisation of the fore limb vessels in the recumbent white rhinoceros. The ventral tail vein can be used for blood collection in the Sumatran rhino (ZZ Zainnudin, personal communication).

Rhino are extremely susceptible to the respiratory depressive effects of the potent opioid agents, etorphine and carfentanil, and can decompensate rapidly.[1-3] Rate and depth of respiration should be carefully monitored in all species. A respiratory rate of 6 to 8 breaths per minute is generally adequate. If there is any concern about the adequacy of the animal's respiration under etorphine or carfentanil anaesthesia, then nalorphine may be administered intravenously in 10 mg increments until an improvement is seen. This will increase the oxygen saturation of the blood and improve the rate and depth of respiration. Doxapram at a total dose of 200 to 400 mg may be given intravenously; this will improve the rate and depth of respiration but will have little effect on the oxygen saturation of the blood when used alone. Administration of nalorphine will lighten the plane of anaesthesia. Signs associated with a lightening plane of anaesthesia include increased ear movements, increased respiratory rates, muscular shivering and attempts to rise. An endotracheal tube may be passed through the nose for the purposes of oxygen supplementation.[7] A standard bovine stomach tube is sufficient. Flow rates of 15 L/min or greater should be used. Captive animals require lower doses of potent opioids to induce sedation or anaesthesia than wild animals where high drug doses are used to facilitate rapid inductions and recumbency.

Cloth earplugs attached to strings can be inserted into the ears to reduce auditory stimulation. A pulse oximeter should be utilised to assist in monitoring the animal's heart rate and for evaluating trends in blood oxygen saturation. Pulse oximetry has not yet been validated in rhinoceros species but appears to be useful for monitoring blood oxygenation trends.[3, 13, 24] The probe may be attached to the ear after the superficial pigmented layers of the skin have been scraped off with a scalpel blade and the skin cleaned with alcohol. Other suitable sites for the attachment of pulse oximeter probes include the prepuce, vulva and the nictitating membrane. Arterial blood samples for the purposes of blood gas analysis can be collected with relative ease from an auricular artery.

Blood pressure should be monitored where possible. Blood pressure can be measured indirectly, with a Doppler probe, sphygmomanometer and a blood pressure cuff, from the coccygeal artery.[13] A piece of foam can also be placed on the medial aspect of the ear and with the cuff then applied around the external ear an indirect reading can be taken from an auricular artery. Direct blood pressure readings can also be taken by catheterisation of an auricular artery.[13, 24] Hypertension has been suspected in several animals and while the direct blood pressure readings that were obtained would represent hypertension in the horse, no blood pressure values are available for conscious, standing rhinoceros.[7, 13, 14] Mean arterial pressures ranging between 210 and 280 mg Hg were considered hypertensive in a white rhinoceros subsequent to etorphine administration.[14] If the blood pressure remains elevated then the intravenous administration of 10 mg nalorphine should lower the animal's blood pressure. The use of intravenous azaperone has been advocated to reduce hypertension in white rhino[7], however intravenous azaperone has been associated with adverse reactions in horses and was implicated in an adverse reaction in one white rhinoceros.[8,23]

Physiological changes associated with recumbency in rhino potentially include hypoventilation, pulmonary shunting and ventilation-perfusion mismatch. Hypoxaemia and hypercapnia have been reported in several recumbent rhinoceros.[3, 6, 13] Atelectasis of the dependant lung was reported following prolonged lateral recumbency in one animal under etorphine based anaesthesia.[13] If the animal's temperature is over 39°C then copious volumes of water should be used to cool the animal.

Renarcotisation has only been reported in the white rhino and animals should be monitored carefully following antagonism of potent opioids.[7, 11] If renarcotisation occurs then the original reversing dose of naltrexone should again be administered. Animals are frequently sedate enough to administer the naltrexone intravenously.

Low doses of etorphine (0.5 to 1.5 mg total dose) administered alone have been used to facilitate crating of white[7], black[1] and greater one horned rhino[5] prior to transportation. Once narcotised, animals will follow a flag over short distances and can be induced to enter transport crates using such a strategy. Opioid antagonists are then administered once the animal is secure. Recumbent animals can be crated following the administration of small doses of nalorphine and upon rising maybe pulled in to the crate with the use of ropes.

Species specific information

Black rhinoceros — Respiratory depression is a potential problem in this species and the routine use of doxapram and nalorphine to counteract this has been included in protocols for free ranging animals immobilised with high doses of etorphine.[1,9] Renarcotisation has not been reported as a problem in black rhino.[1,2,6,9,19,29,30] Excitation during induction seems to occur only in the black rhino and not in the other species. Standing sedation has been achieved with the use of butorphanol at 150 μg/kg and detomidine at 30 μg/kg in the black rhino.[12] Recumbency can also be induced by using 300 μg/kg butorphanol in combination with 60 μg/kg detomidine. Bradycardia and hypoxaemia were noted with this combination. Captive black rhino have been successfully immobilised with carfentanil alone,[19] etorphine alone [19,30] and etorphine in combination with acepromazine[28] or azaperone. Butorphanol alone has been used to sedate a juvenile black rhinoceoros.[21] Total doses approximate those used in white rhino (1700 to 2200 kg) despite the lower body weight of the black rhino (800 to 1350 kg).

White rhinoceros — Inductions with opioid based combinations tend to be calm and predictable in this species. The routine administration of doxapram and nalorphine following recumbency with etorphine-based combinations has been recommended for white rhino.[3] Individuals of this species are good candidates for standing sedation using either etorphine alone[7] or butorphanol in combination with azaperone[8] (Figure 4). A combination of butorphanol and azaperone has been used successfully in white rhino to produce restraint ranging from standing sedation to recumbency.[8] This combination is best suited to calm animals that can be hand injected because of the large volume of drugs required, however the author has effectively administered these drugs by dart in a number of individuals. Butorphanol at an initial total dose of 70 mg and azaperone at an initial total dose of 100 mg should either induce recumbency or standing restraint sufficient for minor manipulations in calm animals. Further butorphanol can be administered intravenously as required or administered as a constant rate infusion.[8] Carfentanil was reportedly used at a mean total dose of 1.2 mg for the immobilisation of five captive, adult, southern, white rhino.[17]

Greater one horned rhinoceros — The response of this species to anaesthetic drugs is similar to that seen in white rhinoceros and anaesthetic protocols for the greater one horned rhino are similar to those used in the white rhinoceros. Etorphine alone[25] and in combination with detomidine[4,5] or acepromazine[18,28] has been most frequently reported for chemical restraint. Recently a combination of etorphine, detomidine and ketamine[5] has been used with favourable results to induce general anaesthesia in greater one horned rhino in several zoological institutions (EJ Flach, personal communication). The use of carfentanil has been reported in a single free-ranging greater one horned rhino.[18] The presence of subdermal plates and heavy skin folds over the shoulder and hind quarters of the greater one horned rhino have led some workers to recommend exclusive use of the neck musculature for dart placement in this species,[28] however in another study in which 51 animals were darted in the muscle masses of the shoulder and hind limb drug delivery was achieved without apparent problems.[18] Despite a similar body weight (1800 to 2200kg) to the white rhinoceros relatively higher doses of etorphine in the initial immobilising combination appear to be necessary to achieve balanced anaesthesia in captive greater one horned rhino.[4,5]

Sumatran rhinoceros — Relatively few anaesthetic events have been performed in Sumatran rhino, given the small numbers of these animals maintained in captivity. Butorphanol has been used alone at a dose of 25 mg administered intramuscularly to induce standing sedation in an adult female sufficient for urethroscopy (RW Radcliffe, personal communication). The animal remained standing in a restraint chute throughout this procedure. Butorphanol at 300 μg/kg and detomidine at 60 μg/kg have been used in combination to produce recumbency in several animals.[12] Etorphine 0.98 to 1.23 mg (total dose) in combination with acepromazine 4 to 5 mg (total dose) administered intramuscularly produced standing restraint sufficient for minor procedures in two adult animals (ZZ Zainuddin, personal communication).

References

1. Kock M. Use of hyaluronidase and increased etorphine (M99) doses to improve induction times and reduce capture related stress in the chemical immobilisation of free-ranging black rhinoceros (*Diceros bicornis*) in Zimbabwe. *J Zoo Wildl Med* 1992;23:181-188.
2. Kock MD, la Grange M, du Toit R. Chemical immobilisation of free-ranging black rhinoceros (*Diceros bicornis*) using combinations of etorphine (M99), fentanyl and xylazine. *J Zoo Wildl Med* 1990;21:155-165.
3. Kock MD, Morkel P, Atkinson M, Foggin C. Chemical immobilization of free-ranging white rhinoceros (*Ceratotherium simum simum*) in Hwange and Matabo National Parks, Zimbabwe, using combinations of etorphine (M99), fentanyl, xylazine and detomidine. *J Zoo Wildl Med* 1995;26:207-209.
4. Atkinson MW, Hull B, Gandolf AR, Blumer ES. Repeated chemical immobilization of a captive greater one-horned rhinoceros (*Rhinoceros unicornis*), using combinations of etorphine, detomidine and ketamine. *J Zoo Wildl Med* 2002; 33:157-162.
5. Gandolf RA, Willis MA, Blumer ES, Atkinson MW. Melting corneal ulcer management in a greater one horned rhinoceros (*Rhinoceros unicornis*). *J Zoo Wildl Med* 2000;31:112-117.
6. Ball RL, Murphy D, Olsen JH, Burton M, Dumonceux G. Multiple isoflurane anesthesia in a captive black rhinoceros (*Diceros bicornis*). *Proceedings of the American Association of Zoo Veterinarians*, 2001:176-178.
7. Raath JP. Anesthesia of white rhinoceros. *In*: Fowler ME, Miller RE, editors. *Zoo and Wild Animal Medicine, Current Therapy 4*. Saunders, Sydney, 1999:556-561.
8. Radcliffe RW, Ferrel TS, Childs SE. Butorphanol and azaperone as a safe alternative for repeated chemical restraint in captive white rhinoceros (*Ceratotherium simum*). *J Zoo Wildl Med* 2001;31:196-200.
9. Reuter H, Winterbach H. Current capture technique and drug dosage regime for the immobilization and tranquillization of free-ranging black rhinoceros (*Diceros bicornis bicornis*) in Namibia. *Proceedings of the American Association of Zoo Veterinarians*, 1998:410-415.
10. du Toit JG. *Rhino Ranching*. Africa Publishers, Pretoria, 1998:31-43.
11. Rogers PS. Chemical capture of the white rhinoceros (*Ceratotherium simum*). In: McKenzie AA, editor. *The Capture and Care Manual*. Wildlife Decisions Support Services, South Africa, 1993:512-533.
12. Blumer E. Restraint and anesthesia. In Fouraker M, Wagener T, editors. *AZA rhinoceros husbandry resource manual*. Fort Worth Zoological Park, 1996;47-49.
13. Heard DJ, Olsen JH, Stover J. Cardiopulmonary changes associated with chemical immobilization and recumbency in a white rhinoceros (*Ceratotherium simum*). *J Zoo Wildl Med* 1991;23:197-200.
14. LeBlanc PH, Eiker SW, Curtis MC, Beehler B. Hypertension following etorphine anaesthesia in a rhinoceros (*Diceros simus*). *J Zoo Wildl Med* 1987;18:141-143.
15. Swan GE. Capture drugs. In: McKenzie AA, editor. *The Capture and Care Manual*. Wildlife Decision Support Services, South Africa, 1993:17-50.
16. Allen JL. A comparison of nalmefene and naltrexone for the prevention of renarcotization following carfentanil immobilization of nondomestic ungulates. *J Zoo Wildl Med* 1996;27:496-500.
17. Allen JL, Janssen DL, Oosterhuis JE, Stanley TH. Immobilization of captive non-domestic hoofstock with carfentanil. *Proceedings of the American Association of Zoo Veterinarians*, 1991:343-353.
18. Dinerstein E, Shrestha S, Mishra H. Capture, chemical immobilization, and radio-collar life for greater one-horned rhinoceros. *Wildl Soc Bull* 1990;18:36-41.
19. Nance MD. Clinical management of severe necrotic laminar disease in an eastern black rhino (*Diceros bicornis michaeli*) associated with an undetermined etiology. *Proceedings of the American Association of Zoo Veterinarians*, 1998: 208-211.
20. Langan J, Ramsay E, Schumacher J, Chism T, Adair S. Diagnosis and management of a patent urachus in a white rhinoceros calf (*Ceratotherium simum simum*). *J Zoo Wildl Med* 2001;32:118-122.
21. Radcliffe RW, Paglia DE, Couto CG. Acute lymphoblastic leukaemia in a juvenile southern black rhinoceros (*Diceros bicornis minor*). *J Zoo Wildl Med* 2000;31:71-76.
22. Moresco A, Larsen RS, Sleeman JM, Wild MA, Gaynor JS. Use of naloxone to reverse carfentanil citrate-induced hypoxemia and cardiopulmonary depression in Rocky Mountain wapiti (*Cervus elaphus nelsoni*). *J Zoo Wildl Med* 2001;32:81-89.

23. Lees P, Serreno L. Effects of azaperone on cardiovascular and respiratory function of the horse. *Br J Pharmacol* 1976;56:263-269.
24. Walzer C, Gsritz F, Pucher H et al. Chemical restraint and anaesthesia in white rhinoceros (*Ceratotherium simum*) for reproductive evaluation, semen collection and artificial insemination. *Proceedings of the American Association of Zoo Veterinarians*, 2000:98-101.
25. Cornick-Seahorn JL, Mikota SK, Schaeffer DO, Ranglack GS, Boatright SB. Isoflurane anaesthesia in a rhinoceros. *J Am Vet Med Assoc* 1995;206:508-511.
26. Klein LV, Cook R, Calle PP et al. Etorphine-isoflurane anaesthesia for ovariohysterectomy in an Indian rhinoceros (*Rhinoceros unicornis*). *Proceedings of the American Association of Zoo Veterinarians*, 1997:127-130.
27. Miller RE, McClure RC, Constantinescu GM, Boever WJ. A clinical note on the vascular anatomy of the black rhinoceros (*Diceros bicornis*) forelimb. *J Zoo Wildl Med* 1998;20:228.
28. Jones DM. The husbandry and veterinary care of captive rhinoceroses. *Int Zoo Yearb*, 1979:19:239-252.
29. Miller RE, Junge RE. Treatment of a nasal ulcer in a black rhinoceros (*Diceros bicornis*) using cryosurgery. *Proceedings of the American Association of Zoo Veterinarians*, 1998:213-215.
30. Baier J, Kenny DE. Salmonellosis (*Salmonella enterica*) in a group of captive black rhinoceros (*Diceros bicornis*). *Proceedings of the American Association of Zoo Veterinarians*, 1997:172-176.

(Accepted for publication 3 February 2004)