Anaesthetic management of a 10-month-old white rhinoceros (*Ceratotherium simum*) calf for emergency exploratory celiotomy

Authors:
Gareth E. Zeiler[1]
George F. Stegmann[1]

Affiliations:
[1]Department of Companion Animal Clinical Studies, University of Pretoria, South Africa

Correspondence to:
Gareth Zeiler

Email:
gareth.zeiler@up.ac.za

Postal address:
Private Bag X04, Onderstepoort 0110, South Africa

A 10-month-old, 580 kg, hand-reared white rhinoceros (*Ceratotherium simum*) calf was presented for emergency exploratory celiotomy. Anaesthesia was safely induced with three successive intravenous (IV) boluses of diazepam (10 mg) and ketamine (100 mg) until the trachea could be intubated. Anaesthesia was adequately maintained with isoflurane-in-oxygen (mean end-tidal isoflurane concentration of 1.1% ± 0.2%) on a circle anaesthetic machine with carbon dioxide absorption and an intravenous infusion of ketamine and medetomidine at a mean rate of 0.02 mg/kg/min and 0.02 µg/kg/min, respectively. Mean values recorded during anaesthesia and surgery were heart rate (56.9 ± 11 beats/min), mean arterial blood pressure (6.16 kPa ± 1.75 kPa), end-tidal carbon dioxide concentration (6.23 kPa ± 0.30 kPa). Abdominal gas distension contributed to hypoventilation that resulted in hypercapnoea, confirmed by arterial blood gas analysis ($PaCO_2$ 14.69 kPa), which required controlled ventilation for correction. Blood volume was maintained with the intravenous infusion of a balanced electrolyte solution at 10 mL/kg/h and blood pressure supported with a continuous infusion of dobutamine and phenylephrine. Duration of anaesthesia was 3.5 h. It was concluded that anaesthesia was safely induced in a compromised white rhinoceros calf with a combination of diazepam and ketamine. A constant-rate infusion of medetomidine and ketamine allowed for a reduction in the dose of isoflurane required during maintenance of anaesthesia and improved intra-operative blood pressure management.

Introduction

Rhinoceros poaching is increasing alarmingly in South Africa (Beech *et al.* 2011), with many rhinoceros calves being left orphaned or killed. The only possibility of survival for these orphans is to be hand-reared in captivity. Many countries have adopted species survival plans (SSPs) that detail breeding guidelines for rare and endangered species, especially captive species (Braude & Templeton 2009). When keeping rhinoceroses in smaller camps in an effort to protect them, an increase in medical- or surgical-related problems may be encountered. Surgical procedures requiring deep sedation or surgical anaesthesia in rhinoceroses to manage conditions such as rectal prolapse (Adams *et al.* 2005; Silberman & Fulton 1979; Stegmann *et al.* 2001), colic (Valverde *et al.* 2010), cancer (Wack *et al.* 2010), toe infections (Harrison *et al.* 2011), and corneal damage (Esson *et al.* 2006) have been described. Adult, free-ranging rhinoceroses are commonly immobilised with etorphine on its own or in combination with azaperone (Adams *et al.* 2005; Bush *et al.* 2004; Esson *et al.* 2006; Harrison *et al.* 2011; Hattingh & Knox 1994; Morkel *et al.* 2010; Portas 2004; Stegmann *et al.* 2001; Vanegas & Schaible 2007; Wack *et al.* 2010; Walzer *et al.* 2010). The rhinoceros calf in this case report was hand-reared and did not require opioid immobilisation to facilitate handling before induction of anaesthesia.

Case report

Case history and diagnosis

'Noster', a 10-month-old, 580 kg, male, hand-reared, white rhinoceros (*Ceratotherium simum*) was referred by a private practitioner for emergency abdominal surgery. For two days it had been demonstrating clinical signs of equine-like colic, including partial anorexia, flank watching, pawing the ground, rolling and not passing faeces. It was transported approximately 150 km to the Onderstepoort Veterinary Academic Hospital (OVAH) in a specially designed steel crate. A 20 G intravenous (IV) catheter had been placed by the referring veterinarian in the right auricular vein and 24 L of a balanced electrolyte solution (Sabax Plasma Vet; Adcock Ingram) had been administered.

On arrival at the OVAH, the calf presented with a body temperature of 35.7 °C, a gas-distended abdomen and signs of nasogastric reflux of a watery-green liquid. Mucous membranes were

pink with no evidence of endotoxaemia. Colonic impaction was suspected after a brief clinical examination. As the calf became non-compliant and agitated during the clinical examination and handling, it was decided not to collect blood for pre-anaesthetic haematological examination. To facilitate handling of the calf and decrease external stimulation whilst walking from the transport truck to the equine clinic for clinical examination and subsequently to a padded large-animal induction room, its eyes were covered with a scarf and its external ear canals plugged with cotton wool.

Induction

For induction and tracheal intubation, a total dose of 30 mg diazepam (dose used 0.05 mg/kg; A-Lennon Diazepam, 5 mg/mL; Aspen Pharmacare) and 300 mg ketamine (dose used 0.5 mg/kg; ketamine, 100 mg/mL; Fresenius Kabi) were injected in three equal aliquots at 3 min intervals. When in sternal recumbency, the calf was pushed into left lateral recumbency and orotracheal intubation was performed blindly. He was intubated with a cuffed, lubricated 18 mm silicon tracheal tube. The head and neck were extended and the mouth opened maximally with the aid of a rope pulling on the mandible. Correct placement was confirmed by the movement of air during expiration. The tracheal tube was secured in position with zinc oxide tape around the muzzle. The tracheal tube was connected to a circle anaesthetic machine equipped with a foal ventilator (Modified Bird Mark 7; J D Medical) and an isoflurane vaporiser (Isotec III, Datex Ohmeda; GE Healthcare) initially set to 5% isoflurane (Isoflurane; Safeline Pharmaceuticals) and fresh gas flow rate 10 L/min. In lateral recumbency the tidal volume of the animal during spontaneous ventilation was approximately 1 L (as observed from the calibration markings on the ventilator bellows). With positive pressure ventilation set at 6 breaths/min, tidal volume increased to approximately 3 L.

TABLE 1: Mean ± standard deviation and range cardiorespiratory and expired gas values during anaesthesia and abdominal surgery in a white rhinoceros (*Ceratotherium simum*) calf.

Monitored parameters	Mean ± s.d.	Range
F (breaths/min)	8.20 ± 5.60	5.00–25.00
HR (beats/min)	56.90 ± 11.00	35.00–71.00
SAP (kPa)	9.13 ± 2.09	6.67–13.47
DAP (kPa)	4.43 ± 1.49	2.67–8.40
MAP (kPa)	6.16 ± 1.76	4.27–10.40
O_2SAT (%)	97.50 ± 2.30	93.00–100.00
ETCO$_2$ (kPa)	6.27 ± 0.30	4.93–11.87
ET$_{iso}$ (%)	1.10 ± 0.20	0.80–1.40

F, ventilation rate; HR, heart rate; SAP, systolic arterial blood pressure; DAP, diastolic arterial pressure; MAP, mean arterial pressure; O_2SAT, haemoglobin oxygen saturation; ETCO$_2$, end-tidal carbon dioxide partial pressure; ET$_{iso}$, end-tidal isoflurane concentration; s.d., standard deviation.

The calf was transported with the aid of an overhead crane and suspended from his limbs into the adjacent surgical theatre and placed in dorsal recumbency. As a stable anaesthetic plane could not be achieved with inhalation anaesthesia, the anaesthetic plane lightened and resulted in limb pedalling. Two additional bolus injections of 10 mg diazepam and 100 mg ketamine were administered IV at 5-min intervals to maintain anaesthesia. In addition, a continuous rate infusion (CRI) of medetomidine (Domitor; Pfizer Animal Health) and ketamine was administered at 180 mL/h (1 g ketamine and 100 µg medetomidine diluted in 200 mL lactated Ringer solution [Intramed Ringers-Lactate solution; Fresenius Kabi] with a final dilution of ketamine 5 mg/mL and medetomidine 0.5 µg/mL). The initial flow rate resulted in a dose of 1.6 mg/kg/h for ketamine and 0.16 µg/kg/h for medetomidine. Intravenous administration of the balanced electrolyte solution continued intra-operatively at 10 mL/kg/h.

Monitoring

A multi-parameter anaesthetic monitor (Cardiocap 5, Datex Ohmeda; GE Healthcare) was used to monitor physiological parameters. The side-stream gas sampler was attached to the Y-piece to monitor end-tidal (ET) isoflurane concentration (%) and ET carbon dioxide (CO_2) partial pressure. Electrocardiography (ECG) pads were placed in a Y-configuration on the manubrium, xiphoid and right scapular region. The pulse oximeter probe was placed on the tongue and an oesophageal temperature probe was placed down the right ventral nasal meatus. Direct arterial blood pressure was measured with an electronic pressure transducer (BD DTX; Becton & Dickson Medical) after a 20 G catheter was placed in a left auricular artery on the medial surface of the pinna. The transducer was zeroed to atmospheric pressure at the level of the scapulo-humeral joint. Dorsal recumbency resulted in compression of the arterial supply to the ears and some lateral tilting of the head was required to relieve pressure on the catheterised ear artery.

Data were recorded at 5 min intervals during the anaesthetic period. Arterial blood was collected in a 2 mL lithium heparinised syringe and analysed within 5 min of collection using a calibrated blood gas machine (Rapidlab® 348 System; Siemens South Africa). The first arterial blood sample was collected when the calf breathed spontaneously on the foal anaesthetic machine, which indicated severe hypercapnoea (14.69 kPa, Table 2). Mean (± s.d., range) parameter values recorded during anaesthesia are presented (Table 1) as well as results of arterial blood gas analysis at the beginning of surgery (Sample 1) and at the end of surgery (Sample 2) (Table 2).

TABLE 2: Arterial blood gas values during anaesthesia and abdominal surgery in a white rhinoceros (*Ceratotherium simum*) calf.

Arterial blood gas sample	pH	PaO$_2$ (kPa)	PaCO$_2$ (kPa)	HCO$_3$std (mmol/L)	BE (mmol/L)	O$_2$SAT (%)
Sample 1[a]	7.130	13.93	14.69	26.6	6.7	95.4
Sample 2[b]	7.316	67.90	6.87	23.5	-1.4	99.9

PaO$_2$, arterial partial pressure of oxygen; PaCO$_2$, arterial partial pressure of carbon dioxide; HCO$_3$std, standard bicarbonate; BE (blood), base excess; O$_2$SAT, haemoglobin oxygen saturation.
[a], At beginning of surgery.
[b], At the end of surgery.

Maintenance

Abdominal distension continued to increase during surgical preparation. It appeared that the foal ventilator failed, as the tidal volume decreased to < 1 L, and the calf could only breathe spontaneously. As surgery started with a ventral midline skin incision, the foal anaesthetic machine was changed to a large-animal anaesthetic machine with ventilator (NA Dräger; Large Animal Control Centre). An unexpected delay during the change to the large-animal anaesthetic machine was experienced due to the difference in connector size of the 18 mm tracheal tube and the Y-piece of the large-animal anaesthetic machine requiring a 28 mm adaptor. The vaporiser was set to 5% with the fresh gas flow rate at 6 L/min. Ventilation rate was initially set at 10 breaths/min with a tidal volume of 6 L. Peak inspiratory pressure increased to 3.90 kPa. Within two minutes, the $ETCO_2$ partial pressure started declining from 11.87 kPa to reach 5.60 kPa after a 30 min period. Thereafter, the ventilation rate was decreased to 4 breaths/min to maintain the $ETCO_2$ between 4.67 kPa and 5.60 kPa. A second arterial blood sample, collected for blood gas analysis after 120 min, indicated a return to a mild hypercapnoea ($PaCO_2$ 6.81 kPa, Table 2).

As mean arterial pressure (MAP) declined to 4.80 kPa at the start of controlled positive pressure ventilation, a second 20 G catheter was placed in the left auricular vein. A dilute solution of dobutamine (dose used 2.5 mg/mL; Dobutamine-Fresenius, 250 mg/20 mL; Fresenius Kabi) was made up with lactated Ringers solution and administered IV by syringe pump (Injectomat Agilla Syringe Pump; Fresenius Kabi) at a rate of 10 mL/h (0.7 µg/kg/min). The dose rate was increased step-wise to 22 mL/kg/h in an attempt to maintain a MAP of 8.00 kPa – 9.33 kPa. In addition, phenylephrine (dose used 10 mg; phenylephrine injection, 10 mg/mL; B.P, Abbott) was added to the balanced electrolyte solution infusion bag (with a final dilution of 33 µg/mL). This increased heart rate from 50 to 65 beats/min and MAP from 5.60 kPa to 8.00 kPa. The CRI of ketamine and medetomidine was decreased to 60 mL/h (i.e. ketamine at 0.5 mg/kg/h and medetomidine at 0.05 µg/kg/h) within 45 min after the infusion was started. Anaesthetic depth was evaluated by autonomic reflexes such as blood pressure and heart rate. The palpebral reflex was absent after anaesthesia stabilised. Ventral rotation of the eyeball was observed during the surgery. The duration of anaesthesia was 3.5 h. The mean body temperature during surgery was 34.5 °C.

For recovery from anaesthesia, the calf was transferred to an equine stall and positioned in right lateral recumbency. He was covered with blankets and warmed with a forced hot-air device. After 40 min, the calf moved into sternal recumbency and maintained this position for five hours before attempting to stand. He accepted milkbottle feeding for the first two days post surgery and began eating solids on the third day. He passed his first stool five days postoperatively and made an uneventful recovery.

For postoperative pain management, flunixin meglumine (dose used 1.1 mg/kg; Finadyne; Schering-Plough AH) was given twice daily via the IV route for the next three days, followed by meloxicam (dose used 0.2 mg/kg; Metacam; Ingelheim) given twice daily by mouth for four days.

Discussion

Anaesthesia in this rhinoceros calf was induced with a combination of diazepam and ketamine and anaesthesia maintained with isoflurane in combination with a CRI of medetomidine and ketamine. Rhinoceroses are sensitive to opioids and readily experience respiratory depression, hypoxaemia, hypertension, pulmonary shunting and ventilation/perfusion mismatching (Hattingh & Knox 1994; Morkel *et al.* 2010; Portas 2004; Silberman & Fulton 1979). Their large body size contributes to the difficulty in anaesthetising these patients (Portas 2004). This calf was hand-reared, however, and did not require opioid immobilisation to facilitate handling before induction of anaesthesia. In this instance, the successive administration of diazepam-ketamine boluses resulted in a calm induction and allowed the drugs to be administered to effect, that is, until tracheal intubation could be performed. Valverde and co-workers (Valverde *et al.* 2010) used guaifenesin and ketamine for induction after premedication with butorphanol and detomidine in an adult white rhinoceros for colic surgery. In the calf, ventilation was spontaneous without induction apnoea but a decrease in tidal volume was a major concern as abdominal gas distension may increase pressure on the diaphragm once the patient is in lateral recumbency.

Orotracheal intubation was complicated by reflex swallowing, but with extension of the head and neck, tracheal intubation was performed with minimum delay. Other techniques that are described include palpation of the oropharynx to guide a stomach tube into the trachea to be used as a guide for the endotracheal tube (Stegmann *et al.* 2001; Valverde *et al.* 2010), but for this calf the oral cavity was too limited to consider that technique. Use of a long-blade laryngeal scope to facilitate orotracheal intubation is described in one case (Adams *et al.* 2005). Nasotracheal oxygen insufflation by stomach tube has been described in field-immobilised rhinoceroses (Bush *et al.* 2004). The only possible advantage of blind oral intubation is that the oral cavity of the white rhinoceros is very confined, which may facilitate guiding the tracheal tube to the laryngeal opening.

The presence of gastric reflux in the oral cavity resulted in some debate over the advantages of flushing foreign material from the oral cavity before intubation. The confined oral cavity and inability to confirm drainage of the flush fluid increased the risk of fluid aspiration. On extubation, grassy particulate matter was found on the inside of the endotracheal tube. The calf coughed a few times during the recovery period, which may have been attempts to remove the particulate matter from the trachea. No post-anaesthetic aspiration pneumonia or lung and trachea complications were observed.

Halothane (Stegmann *et al.* 2001) and isoflurane (Adams *et al.* 2005; Valverde *et al.* 2010), both administered in oxygen, have

been used for anaesthetic maintenance. Anaesthesia may also be maintained with intermittent intravenous ketamine boluses (Wack *et al.* 2010; Walzer *et al.* 2010), detomidine and etorphine (Harrison *et al.* 2011) or ketamine, detomidine and guaifenesin (Esson *et al.* 2006). Partial intravenous anaesthesia (PIVA) as a CRI has not been described before for the rhinoceros. In this instance, a CRI was initially set for ketamine (1.6 mg/kg/h) and medetomidine (0.16 µg/kg/h) during surgery. A possible advantage of this technique was that the dose of isoflurane could be reduced to improve arterial blood pressure as the mean end-tidal isoflurane (ET_{iso}) concentration during anaesthesia was 1.1% ± 0.2%, decreasing to a minimum of 0.8%. The minimum alveolar concentration (MAC) for isoflurane in the rhinoceros is not known and therefore it was intended to maintain the concentration similar to the concentration used at this institution for PIVA during equine surgery at 1.3%. The MAC for isoflurane in the equine is 1.31% (Steffey *et al.* 1977). Valverde *et al.* (2010) recorded the isoflurane vaporiser setting of 1.5% – 2% compared with a mean of 1.2% during the calf's surgery, demonstrating a marked reduction in the isoflurane concentration most likely due to the CRI of ketamine and medetomidine. However, owing to the low intra-operative blood pressure (MAP 6.16 kPa ± 1.76 kPa, Table 1) the ET_{iso} was further reduced and the ketamine-medetomidine CRI reduced step-wise to 60 mL/h (ketamine 0.5 mg/kg/h, medetomidine 0.05 µg/kg/h). Healthy, unsedated adult white rhinoceroses have an MAP 16.53 kPa ± 0.30 kPa (Citino & Bush 2007). Bolus administration of anaesthetic drugs during surgical anaesthesia to maintain anaesthesia may contribute to adverse cardiovascular effects such as decreases in blood pressure. The ketamine-medetomidine CRI and low isoflurane dose contributed to a stable anaesthetic plane despite initial difficulties to ventilate the rhinoceros. Both ketamine (Bantel *et al.* 2007) and medetomidine (Vanegas & Schaible 2007) are drugs with known analgesic activity that will help reduce the dose of isoflurane.

A previously reported blood gas analysis of a 2000 kg anaesthetised rhinoceros revealed hypercarbia, hypoxaemia and acidaemia due to its large size and sensitivity to opioid-based drugs causing hypoventilation, and despite positive pressure ventilation, the arterial oxygen carbon dioxide partial pressures ($PaCO_2$) did not resolve (Valverde *et al.* 2010). The body size of the rhinoceros, abdominal distension, and lack of immediate blood gas analysis results could have contributed to the adverse results. In this calf, the body weight was much smaller (580 kg) although abdominal gas distension also played a major role in hypoventilation resulting in a $PaCO_2$ of 14.70 kPa. It was speculated that dorsal recumbency and a further increase in abdominal gas distension resulted in failure of the foal ventilator. The foal ventilator was tested later and found to be in a good working condition and no mechanical cause of the ventilator failure whilst connected to the calf could be found. When connected to the large animal ventilator, $ETCO_2$ values started to decrease. Two hours later, a second arterial blood sample was taken that confirmed improved ventilation with a $PaCO_2$

of 6.87 kPa. The abdominal incision and exteriorising the gas distended gut also relieved pressure on the diaphragm to improve ventilation.

The pulse oximeter probe is typically placed on an ear tip after the superficial epidermal layer is scraped clean (Walzer *et al.* 2010). In this case, the probe was placed on the tongue. Unlike in horses, the tongue of the calf was thin and a reliable probe apposition could be obtained. The haemoglobin oxygen saturation results ranged from 93% to 100%. Indirect blood pressure readings using an oscillometric device have been described (Adams *et al.* 2005). Due to the skin thickness on the leg, the results may be underestimated. Opioids, especially the more potent etorphine and carfentinil promote moderate to severe hypertension (Hattingh & Knox 1994; Morkel *et al.* 2010; Portas 2004). The partial-agonists of the opioids may be used to decrease the respiratory depression and hypertensive effects associated with the potent opioids (Portas 2004). In some cases, the maintenance of blood pressure requires the use of sympathomimetics such as dobutamine, alone (Valverde *et al.* 2010) or in combination with phenylephrine (Adams *et al.* 2005). The reported MAP using an invasive method and using a similar anaesthetic technique was 8.27 kPa (Valverde *et al.* 2010). The calf had an MAP of 6.16 kPa ± 1.76 kPa (Table 1). The low blood pressure was minimally responsive to a decrease in anaesthetic dose. In this instance, dobutamine was first administered alone in increasing doses and later phenylephrine was added to the maintenance fluids. It was possible to maintain the ET_{iso} concentration at a mean of 1.1% for surgical anaesthesia thanks to the additive effect of the ketamine and medetomidine. Both drugs should improve blood pressure due to the sympathomimetic effect of ketamine on cardiac contractility and the peripheral vasoconstrictor effect from medetomidine (Plumb 2008). It appeared that the rhinoceros was less responsive to the peripheral vasoconstrictor effects of medetomidine and phenylephrine. It is the authors' experience that when combining these drugs during equine anaesthesia, the pulse oximeter curve amplitude continues to decrease as the anaesthesia progresses in time until it becomes a flat line, even in horses that are endotoxic. In this rhinoceros, the pulse contour amplitude was large and remained unchanged during anaesthesia.

Factors that could have contributed to the low intra-operative blood pressure are its young age, as young animals tend to have a lower blood pressure than adults, although young animals also tend to respond better to positive chronotropic agents to increase their arterial blood pressure (Doherty & Valverde 2006). The calf's blood pressure increased minimally despite an increase of heart rate from a low of 35 beats/min 71 beats/min (Table 1). A possible explanation could be endotoxin release with handling of the intestines resulting in vasodilatation and a drop in blood pressure. A diagnosis of colonic impaction and displacement of the dorsal colon was made after the celiotomy. The impaction of the colon was resolved by enterotomy of the caecum and colon. Hypovolaemia is also a possible cause

of the consistently low arterial blood pressure readings, as no haematocrit or total serum protein values were obtained to confirm hypovolaemia. The arterial line in the auricular artery was initially subjected to partial compression in dorsal recumbency as a result of the head compressing the ear on the foam mattress of the large animal surgical table. This could have contributed to the low blood pressure readings in the early stages of surgery but this was corrected by slight lateral tilting of the head with the aid of sand bags. The calf had a low core body temperature on arrival (35.7 °C) at OVAH and during general anaesthesia (34.5 °C) compared with 36.8 °C ± 0.1 °C of a healthy, unsedated adult white rhinoceros (Portas 2004). This could have contributed to the low arterial blood pressure and low anaesthetic requirements recorded in this case.

Conclusion

This case demonstrated that anaesthesia may be induced in a compromised white rhinoceros calf with a combination of diazepam and ketamine. Maintenance of anaesthesia can be achieved by supplementing isoflurane anaesthesia with a constant rate infusion of medetomidine and ketamine. This allows for a reduction in the dose of isoflurane required during maintenance of anaesthesia and improved intra-operative blood pressure management.

Acknowledgements
Competing interests

Authors' contributions

G.F.S. (University of Pretoria) was the senior anaesthetist responsible for the general anaesthesia during the colic operation. G.E.Z. (University of Pretoria) was co-anaesthetist and wrote the publication under the guidance of G.F.S. (University of Pretoria).

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