ANESTHESIA IN A CAPTIVE JUVENILE BLACK RHINOCEROS (*DICEROS BICORNIS*) FOR MAGNETIC RESONANCE IMAGING AND COMPUTED TOMOGRAPHY

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Abstract: A hand-reared, 53-kg, female, 30-day-old black rhinoceros (*Diceros bicornis*) calf presented for magnetic resonance imaging and computed tomography after demonstrating neurologic signs. The rhino was premedicated intramuscularly with butorphanol and midazolam, yielding satisfactory sedation. Induction was achieved using intravenous propofol until the trachea could be intubated. Anesthesia was maintained with sevoflurane in 100% oxygen (mean end-tidal concentration of $2 \pm 0.5\%$). Mean values recorded during anesthesia included were heart rate, end-tidal carbon dioxide, respiratory rate, noninvasive blood pressure, and pulse oximetry. A balanced electrolyte solution of 10 mL/kg per hour was given intravenously. It was concluded that anesthesia was safely induced and maintained with a combination of butorphanol, midazolam, propofol, and sevoflurane. Total anesthesia time was 3 hr, with no perianesthetic complications and an uneventful recovery.

Key words: Anesthesia, black rhinoceros, *Diceros bicornis*, imaging, rhinoceros calf.

BRIEF COMMUNICATION

The black rhinoceros (*Diceros bicornis*) is a high-profile species that is facing extinction in the wild primarily through poaching.[6] Currently, the black rhino is categorized as IUCN Red List Critically Endangered, making its conservation a highly publicized global issue. As conservation efforts increase, both medical and anesthetic protocols are required for appropriate and safe management of wild and captive rhino. Current anesthetic regimens usually involve intramuscular delivery of various agents via darting, as the rhino is often not tractable to handling. This is usually accomplished using etorphine on its own or in combination with azaperone, detomidine, and or other drugs.[1–3] Furthermore, there are very few reports of anesthesia in young rhino calves; most anesthetic protocols are designed for either adult captive or wild free-ranging adults, not young calves capable of being manually restrained. In-depth procedures such as surgery and advanced imaging modalities, like magnetic resonance im-

aging (MRI), require long durations of anesthesia. Furthermore, because of medical advancements, the likelihood of advanced imaging and invasive surgical procedures is becoming more prevalent. Therefore, there is need for diverse anesthetic protocols as greater numbers of rhino enter captivity for conservation and population management.

A 53-kg, female, 30-day-old black rhinoceros calf presented to Texas A&M University Large Animal Hospital for evaluation of depression, lethargy, abnormal posturing with head pressing, and reluctance to walk forward. Cursory examination confirmed these neurologic abnormalities and there was a high index suspicion of a central nervous system derangement. Therefore, the rhino was housed in an isolation stall because of neurologic manifestations. All animals that present with neurologic dysfunction are generally placed into an isolation stall until they are assessed and clear from infectious diseases. The internal medicine and anesthesia services coordinated to anesthetize the rhino in the isolation stall with transport to the hospital's imaging center for both an MRI and a computed tomography (CT) scan.

Prior to induction of anesthesia, the rhino calf was manually restrained and hand injected intramuscularly with 2 mg butorphanol (Torbugesic® 10 mg/ml, Zoetis, Florham Park, New Jersey 07932, USA; 0.04 mg/kg i.m.) and 5 mg midazolam (Midazolam® 5 mg/ml, Hospira, Lake Forest, Illinois 60045, USA; 0.1 mg/kg i.m.), producing marked sedation effects within 15 min. The initial vital parameters taken after premedi-

Table 1.   Venous blood gases. Venous blood gas analyses of a juvenile *Diceros bicornus* postinduction during sevoflurane anesthesia at two different time points. The time points were 30 and 150 min after the start of inhalant anesthesia.[a]

Time (min)*	pH	PvO₂ (mm Hg)	PvCO₂ (mm Hg)	HCO₃ (mEq/L)	BD (mEq/L)	Na (mEq/L)	K (mEq/L)	iCa (mmol/L)	PCV (%)	TP (mg/dl)
30	7.335	96.6	41.4	23.6	−3.7	129.4	4.06	1.29	28.2	7.4
150	7.306	177.0	41.9	22.4	−5.5	129.9	4.31	1.32	29.9	7.0

[a] Time is expressed in minutes, and time zero is the start of inhalant anesthesia; therefore, time 30 is 30 min after the start of inhalant anesthesia. PvO₂ = venous oxygen tension; PvCO₂ = venous partial pressure of carbon dioxide; HCO₃ = bicarbonate; BD = base deficit; Na = sodium; K = potassium; iCa = ionized calcium; PCV = packed cell volume; TP = total protein.

cation were temperature (99.2°F), heart rate (96 beats/min), and respiratory rate (20 breaths/min). Vital parameters were not taken prior to sedation to avoid any more stress placed on the young rhino. A 20-ga short-term intravenous catheter (Jelco® I.V. Catheters, Smiths Medial, Dublin, Ohio 43017, USA) was placed in the auricular vein of the left ear and secured with tape and tissue adhesive. Thirty minutes postpremedication, the rhino was placed in sternal recumbency and induced with 210 mg propofol (PropoFlo™ 10 mg/ml, Abbott Animal Health, Abbott Park, Illinois 00000, USA; 4 mg/kg i.v.). Once induction was achieved, the rhino was intubated with a full-length 12-mm internal diameter Murphy endotracheal tube for maintenance of airway and delivery of gas anesthesia. The endotracheal tube was placed easily, guided by long-bladed laryngoscope (300 mm) and stylet; the cuff was inflated to appropriately seal the tracheal tube, and it was estimated that a 14-mm internal diameter endotracheal tube would have easily fit.

The rhino was attached to a portable anesthesia machine (Matrx VMS®, Midmark, Dayton, Ohio 45409, USA) using a standard adult F-circuit with a semiclosed circuit. Initial oxygen flow rate was 1 L/min and the sevoflurane vaporizer setting was at 1%. The vaporizer setting was initially set lower than reported MAC (minimum alveolar concentration) values for sevoflurane in various species. This was done to prevent a surgical plane of anesthesia. The rhino was to remain heavily sedated during transportation, and with a lower vaporizer setting there is an overall decrease in the amount of side effects that can occur for increasing amounts of inhalant. The rhino was placed on a magnetic resonance–safe gurney and transported to the imaging center for MRI. Vital parameters monitored during the MRI were pulse oximetry, electrocardiogram, capnography, respiration rate, end-tidal sevoflurane concentration, inspired oxygen concentration, and noninvasive blood pressure. A single attempt was made to place an

arterial line in the auricular artery, but this was unsuccessful. The rhino calf was placed on a ventilator (Mallard®, Mallard Medical Inc., Redding, California 96002, USA) with the following settings: tidal volume of 500 ml, oxygen flow rate of 3 L/min, and peak inspiratory pressure of 15 cm H₂O. The rhino was started on 20 ml/kg of lactated Ringer solution intravenously (Lactated Ringer's Solution USP, Hospira; 10 ml/kg per hour i.v.).

The end-tidal sevoflurane concentration was maintained between 1.8 and 2%, in 100% oxygen, for the duration of the MRI procedure. Two venous blood samples were taken during the scan for blood gas analysis and the results were within acceptable limits (Table 1).[4] After completion of the MRI the rhino was transported to the adjacent room for CT scan, at which time monitoring equipment was reconnected and anesthesia was maintained via intermittent positive-pressure ventilation for the duration of the full-body CT. After completion of the scan, the patient was transported to a recovery stall for collection of additional blood and cerebrospinal fluid. After sample collection, gas anesthesia was turned off and the rhino received supplemental oxygen for 10 min before inhaling room air via spontaneous respirations. The rhino was then transported back to the isolation stall for monitoring of recovery. Total anesthesia time was 3 hours and 5 min. The patient was mildly hypothermic post anesthesia and (temperature 94.7°F) required blankets, warm water bottles, and a heat lamp. The rhino was extubated 25 min after discontinuing inhalant and was sternal 40 min postanesthesia.

This rhinoceros calf was successfully sedated with butorphanol and midazolam, induced with propofol, and anesthesia maintained with low doses of sevoflurane in 100% oxygen. Both induction and recovery were smooth and uneventful. Rhinoceroses are sensitive to the effects of opioids and readily will experience respiratory depression; furthermore, this is the first report of which the authors are aware of anesthesia in a

Table 2. Physiologic parameters. Average value of select physiologic parameters of a juvenile *Diceros bicornus* during sevoflurane inhalant anesthesia.

Rectal temperature (°C)	Heart rate (beats/min)	Respiratory rate (breaths/min)	SpO_2 (%)	End-tidal CO_2 (mm Hg)	Indirect systolic pressure (mm Hg)	Indirect diastolic pressure (mm Hg)	Indirect mean arterial pressure (mm Hg)
35.3 ± 1.7	61.9 ± 15.5	19.4 ± 5.3	95.2 ± 3.8	47.3 ± 5.6	70.9 ± 6.8	40.6 ± 13.0	47.3 ± 12.3
36.7 ± 0.1[a]	39 ± 0.8[a]	19 ± 0.6[a]	97.2 ± 0.1[b]	45.1 ± 0.7[a]	160 ± 2.9[a]	78 ± 2.2[a]	102 ± 3.1[a]

SPO_2 = percent oxygen saturation of hemoglobin

[a] Reference physiologic data from 12 healthy, adult, standing, unrestrained captive white rhinoceroses (*Ceratotherium simum*).

[b] Value taken from arterial sample.

rhinoceros less than 35 days of age.[9] There is an increased risk of anesthetic-related complications in neonates as cardiopulmonary physiology transitions to adult life, with hypoxia, hypercapnia, and acidosis commonly encountered.[7] The complication that was encountered during anesthesia of this rhino was the inability to obtain continuous monitoring. The noninvasive blood pressure monitoring during the MRI procedure was inconsistent. The authors are unaware of any studies that have used and/or validated physiologic parameters in young rhinoceros calves under inhalant anesthesia or other reported physiologic parameters in neonatal or juvenile rhinoceros that are not anesthetized. Because of the increased length of various diagnostic and or surgical procedures, the reliability of oscillometric blood pressure should be validated in this species prior to making assumptions about hypotension. Furthermore, most pediatric patients tend to have a more compliant cardiovascular system, which makes them more susceptible to the vasodilatory effects of inhalants.[8] Therefore, the lowest possible amount of sevoflurane was used to allow a lighter plane of anesthesia. The pulse oximeter periodically failed to measure oxygen saturation. This could be due to a variety of factors, including arterial desaturation; however, the skin thickness and deep pigmentation of the rhino's skin were suspected as interfering with measurement. When the pulse oximetry was placed on the vulva, the measurements were consistent; however, the probe that is utilized in the MRI unit is not adaptable for a variety of different anatomical locations. In addition, most monitoring equipment is temporarily disrupted when the MRI machine is actively scanning. Mean values for monitoring parameters obtained are listed (Table 2). These values can be compared to reference values available for standing, unanesthetized rhinoceroses.[4] The venous blood gas measurements were helpful for gauging ventilation and acid-base status.

The hypothermia and prolonged recovery postanesthesia were expected, as the two are correlated after long anesthetic events.[5] Thermal support during the procedure was limited to blankets during the MRI, because of strict prohibition of ferrous materials in the magnet. There are several explanations for why there was a prolonged recovery. Hypothermia can alter drug distribution and drug elimination. Additionally, pediatric and neonatal populations have differing drug uptake, distribution, and metabolism. The blood-brain barrier is more permeable, leading to a potentiation of pharmacologic central nervous system effects. Because of pediatric increased body water and lower fat content there is a greater initial volume of distribution for water-soluble drugs and a smaller volume of distribution for lipid-soluble drugs.[8]

This particular rhinoceros was anesthetized two additional times after the initial event, using the same anesthetic protocol. The other two anesthetic events had no adverse outcomes and the physiologic parameters during those events mirrored the initial parameters obtained. Furthermore, this rhinoceros was diagnosed with an abscess in the lumbar region of the spinal canal and hospitalized for intensive medical management. In conclusion, this was an effective anesthetic protocol used to facilitate advanced imagining and diagnostics of a captive juvenile black rhinoceros calf.

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