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ZOO & WILD ANIMAL MEDICINE

Current Therapy - 4

W.B. SAUNDERS COMPANY
A Division of Harcourt Brace & Company
Philadelphia London Toronto Montreal Sydney Tokyo

1995

PERRISODACTYLIDS

CHAPTER 80

Skin Diseases of Black Rhinoceroses

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The captive population of black rhinoceroses (*Diceros bicornis*) has had persistent health problems that have impeded population growth,[9] and the most prevalent health problem has been skin disease. In the United States, nearly 50% of adult black rhinoceroses have had at least one episode of skin or oral/nasal mucosal lesions that resulted in significant morbidity and, less commonly, mortality. Although some skin conditions appear as primary disease, most episodes appear to be secondary to other major health problems, such as hepatic failure, hemolytic anemia, enteritis, pneumonia, and generalized debility. Many episodes have also been linked to stressful environmental conditions, such as transportation, introduction of new animals, or sudden cold temperatures. The relationship between skin disease and other conditions suggests that rhinoceros skin is acutely sensitive to the physiologic status of the animal and that events disrupting normal homeostasis may initiate structural and functional changes in the epidermis that result in increased fragility and poor healing. The distinctive dermatologic syndrome that accounts for the majority of lesions in captive black rhinoceroses, superficial necrolytic dermatopathy, is consistent with this concept. In contrast, skin disease in wild black rhinoceroses has been almost exclusively associated with *Stephanofilaria dinniki* infestations.

NORMAL SKIN HISTOLOGY

Black rhinoceros skin has features that most closely resemble those of human skin except for the deep collagenous dermis. Rhinoceros epidermis has prominent rete ridges and a distinct papillary dermis (Fig. 80–1). The epidermis is composed of approximately 5 to 10 layers of keratinocytes covered by several layers of cornified epithelial cells. The papillary dermis is notably less dense than the dermis below the rete ridges (reticular dermis), which is very thick (up to 2 cm) and composed of dense, interwoven collagen bundles. The skin has sparse hair with only rare, small pilosebaceous units. Evenly dispersed in the superficial reticular dermis are large, round clusters of eccrine sweat glands and prominent arterioles. These histologic characteristics suggest that black rhinoceros skin lacks the protective benefits of hair and the moisturizing effects of sebum but can rapidly disperse heat through eccrine gland secretion and abundant superficial vasculature. The epithelium of the oral and nasal mucosa is similar

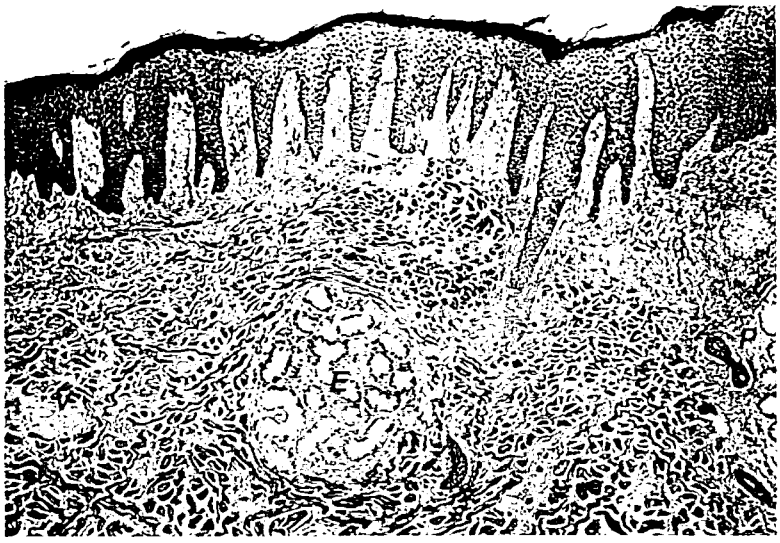

FIGURE 80–1. Histologic appearance of normal black rhinoceros skin. The reticular dermis is markedly collagenous and contains eccrine sweat glands (E) and scant pilosebaceous units (P). The epidermis is thin and has rete ridges. Hematoxylin and eosin stain; original magnification, ×400.

to the skin except that the superficial cells do not undergo cornification.

RESPONSES OF RHINOCEROS SKIN TO INJURY

Skin pustules and ulcers develop in black rhinoceroses under many circumstances, and only histopathologic study can distinguish the primary dermatologic problem. For this reason, this chapter emphasizes the histologic character of skin lesions.

Black rhinoceros skin has common responses to a variety of injuries. The skin undergoes marked epidermal hyperplasia, increasing in depth up to 30 or more layers, and rete ridges become complex and branching. Stratification of keratinocytes often becomes disorganized, and multinucleated keratinocytes appear. Altered epidermal keratinization is also common and results in dyskeratosis, parakeratosis, and hyperkeratosis. If cytokeratin immunohistochemistry or electron microscopy is not used, dyskeratotic epithelial cells may contain distinct eosinophilic keratin aggregates that can be mistaken for viral inclusions.

The papillary dermis responds to many injuries with marked neovascularization, edema, hemorrhage, and an increase in basophilic fibrillar ground substance. Hemorrhage also is common in the superficial reticular dermis, and red blood cell (RBC) exocytosis through the epithelium (which has been described as "sweating blood") results in subcorneal pooling of blood or hemorrhagic crusts. In most types of injury, dermal fibroplasia is prominent and disorganized, appearing similar to neoplasia. Neutrophils and eosinophils are the predominant inflammatory cells in most rhinoceros skin diseases, and melanophages are common in chronic inflammatory conditions because pigmentary incontinence occurs.

Ulcers, erosions, and fissures develop under many circumstances, possibly because rhinoceros skin has a relatively thin, unprotected epidermis overlying a rigid, collagenous dermis. Ulcers typically heal slowly, and the epidermis at ulcer margins can be very hyperplastic, forming large, fungating, neoplasm-like masses (pseudocarcinomatous hyperplasia). Dense granulation tissue beds form under most chronic ulcers and are often accompanied by collagen degeneration and mineralization.

SPECIFIC DERMATOLOGIC SYNDROMES

Superficial Necrolytic Dermatopathy of Black Rhinoceroses

Synonyms for this condition are mucosal and cutaneous ulcerative syndrome, hepatocutaneous syndrome, vesicular and ulcerative dermatopathy, and ulcerative skin disease. It is the most prevalent skin disease in captive black rhinoceroses and is characterized by abnormal epidermal growth, degeneration, and superficial necrosis, subsequently leading to the formation of vesicles and chronic ulcers.[11] More than 40 rhinoceroses in 21 zoological parks have been affected by this syndrome. Clinically, lesions first appear as epidermal plaques, vesicles, or pustules that subsequently erode or ulcerate. In many cases, ulcers are the first noted clinical sign and are often mistaken for abrasions when located over pressure points. The lesions are usually bilateral and relatively symmetric, located predominantly on pressure points, ear margins, coronary bands, the tip of the tail, or the lateral body surfaces. Oral or nasal mucosal lesions also occur alone or concurrently with skin lesions. Most oral lesions are on the palate or the lateral margins of the tongue or lips in contact with teeth.

The clinical course is typically one of a waxing and waning of lesions. Most rhinoceroses with lesions are anorectic and have a depressed attitude and weight loss.

Generalized weakness and unexplained lameness also accompany these lesions. Rhinoceroses with extensive skin involvement become moribund. In many rhinoceroses, serum albumin, cholesterol, and hematocrits are lower than those in unaffected wild or captive black rhinoceroses, which may reflect the direct loss of albumin and blood through the skin.

The lesions have distinctive histopathologic characteristics. Early lesions are characterized by epidermal hyperplasia, intraepithelial edema, hydropic degeneration of keratinocytes, and parakeratosis (Fig. 80–2). Vesicles or pustules form in the epidermis at sites of degeneration and edema, resulting in superficial epidermal necrosis. Ulcers subsequently occur after minimal trauma, and the ulcers expand peripherally and heal poorly. A dermal inflammatory reaction does not occur until the ulcerative stage, and it is confined to areas with exposed dermis. Secondary superficial bacterial infections are common.

The disease appears in rhinoceroses of all ages (range of 1 to 39 years) and under different management strategies, with different diets, and under different environmental conditions. The disease occurs as a primary condition or (more commonly) in association with other medical conditions, such as toxic hepatopathy, hemolytic anemia, gastrointestinal diseases, and respiratory infections. The primary disease is often associated with stress events such as sudden cold temperatures, transportation, introduction of new animals, or parturition.

This ulcerative dermatopathy has clinical and histologic features of a rare degenerative skin disease in other species, known as superficial necrolytic dermatitis (hepatocutaneous syndrome) of dogs[2, 10] and necrolytic migratory erythema of humans.[5, 6] These conditions are usually caused by hyperglucagonemia or other metabolic derangements leading to hypoaminoacidemias. The specific cause of this condition in black rhinoceroses has not been identified, although glucagon and amino acid levels have not yet been measured. The high prevalence of this syndrome exclusively in the captive population suggests a dietary deficiency or a metabolic change resulting from captivity.

Because the cause is unknown, treatment has been empiric. No treatment has consistently succeeded in reversing these lesions, and many lesions resolved without treatment. Secondary bacterial infections can be effectively controlled with topical or systemic antibiotics, topical antiseptics, moisturizing salves, and hydrotherapy. Affected rhinoceroses should be examined for underlying diseases, and management practices should be evaluated for dietary adequacy and potential stress factors. Biologic samples (from biopsies of lesions and from plasma and serum) from current cases and recording of environmental and management factors during emerging cases will contribute significantly toward establishing the cause of this condition.

Epidermal Exfoliation

Rhinoceroses sometimes exfoliate large sheets of superficial epidermis from their flanks and lateral thorax, exposing an underlying grey, shiny epidermis. Histologically, the exfoliated material is composed of multiple layers of degenerating superficial epidermis with hyperkeratosis and parakeratosis. The similarity of the epidermal changes with those of the superficial necrolytic dermatopathy and the occurrence of these two syndromes in the same rhinoceroses at different times suggests that this exfoliative syndrome is a clinical variant of superficial necrolytic dermatopathy. The syndrome has resolved without complications after topical moisturizing and antiseptic treatments.

Superficial Pustular Dermatitis

Superficial pustules and serocellular crusts commonly occur in black rhinoceros skin. Although most pustules are secondary to superficial necrolytic dermatopathy, intraepithelial pustules occur in rare cases without epithelial degeneration. Primary superficial pustular derma-

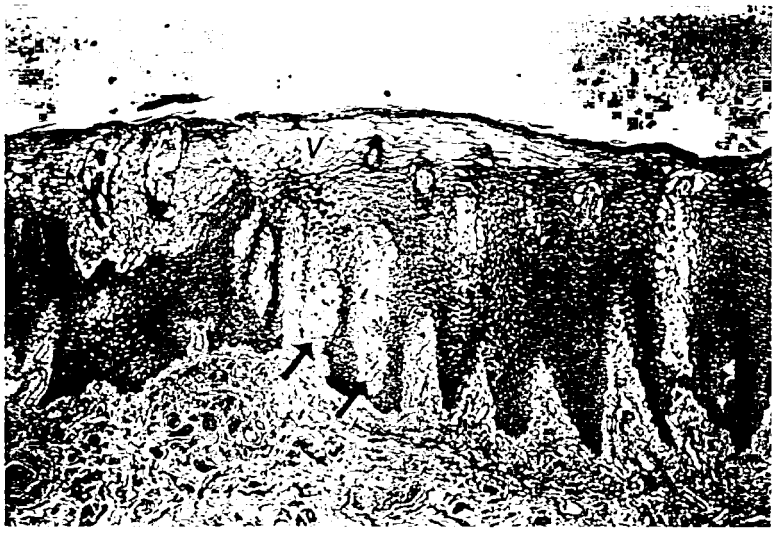

FIGURE 80–2. Black rhinoceros skin with superficial necrolytic dermatopathy. The epidermis is hyperplastic and degenerating, and intercellular edema leads to formation of an early vesicle (V). Parakeratosis also is present. The dermis has vascular dilation and proliferation (*arrows*) but lacks inflammation. Hematoxylin and eosin stain; original magnification, ×400.

titis is characterized by accumulations of neutrophils and small numbers of eosinophils in the epidermis, usually directly beneath the stratum corneum, resulting in small (1- to 2-mm) pustules (Fig. 80–3). Less commonly, transepidermal coagulative necrosis occurs in association with superficial neutrophil accumulations and colonies of bacterial cocci (*Staphylococcus* species). Dermal inflammatory reactions accompany these lesions. These lesions are similar to staphylococcal pyoderma in other species.[1] Most cases have resolved with appropriate topical or systemic antibiotic therapy.

Collagenolytic and Eosinophilic Diseases

NODULAR COLLAGEN DEGENERATION

Dermal collagen degeneration with dystrophic mineralization occurs alone or adjacent to chronic ulcers from other causes. The primary disease manifests as rapidly developing irregular plaques in the oral or nasal cavities or in the dermis. Histologically, the dermis contains discrete areas of collagen degeneration, usually with dystrophic mineralization and surrounded by aggregations of macrophages and inflammatory giant cells (Fig. 80–4). The overlying epidermis is unaffected. The cause of these lesions has not been determined, although similar lesions are seen in domestic dogs with hyperglucocorticoidism and in domestic horses with nodular collagenolytic granuloma, which are suspected to be caused by arthropod induced injury.[17] Collagen degeneration and mineralization also are a feature of eosinophilic granulomas in black rhinoceroses (see next section). Lesions of collagen degeneration have been successfully treated by excision, and untreated lesions have been described as eventually exuding chalky material.

EOSINOPHILIC DERMATITIS AND GRANULOMAS

Eosinophils are a common minor component of the dermal inflammatory response of black rhinoceroses, but in some cases eosinophilic infiltrates predominate. Eosinophilic dermatitis is usually accompanied by eosinophilic granulomas and ulcers, most of which are associated with collagenolysis and mineralization. Most eosinophilic granulomas and ulcers occur in the oral and nasal cavities and are similar to indolent ulcers in domestic cats.[1] No parasitic or fungal agents are associated with these lesions in captive rhinoceroses, whereas in wild black rhinoceroses, eosinophilic granulomas commonly develop during bouts of stephanofilariasis.[7]

Allergic and Arthus-Like Reactions

Some rhinoceroses have manifested acute skin lesions in response to vaccinations or systemic antibiotics. One animal had small vesicles or pustules over the entire body, whereas other rhinoceroses appeared to exude blood through the skin. The pathologic basis for the hemorrhagic responses has not been determined, although vascular injury is most likely. An Arthus-like reaction (dermal vascular necrosis, thrombosis, and epithelial necrosis) has occurred in association with ulcers in other rhinoceroses, although these animals had not recently undergone systemic treatments or vaccination. However, these Arthus-like lesions also occur with frostbite, which may indicate that they are not immune mediated.

Viral Skin Diseases

A poxvirus was isolated from a rhinoceros with vesicles and pustules in a European zoo,[3, 12, 13] but no poxviral lesions have been reported in other captive and wild populations. Pox-like intracytoplasmic inclusions have been noted in the keratinocytes of captive rhinoceroses in the United States with superficial necrolytic dermatopathy, but these inclusions were determined by electron microscopy and immunohistochemistry to be composed of keratin intermediate filament aggregates. An

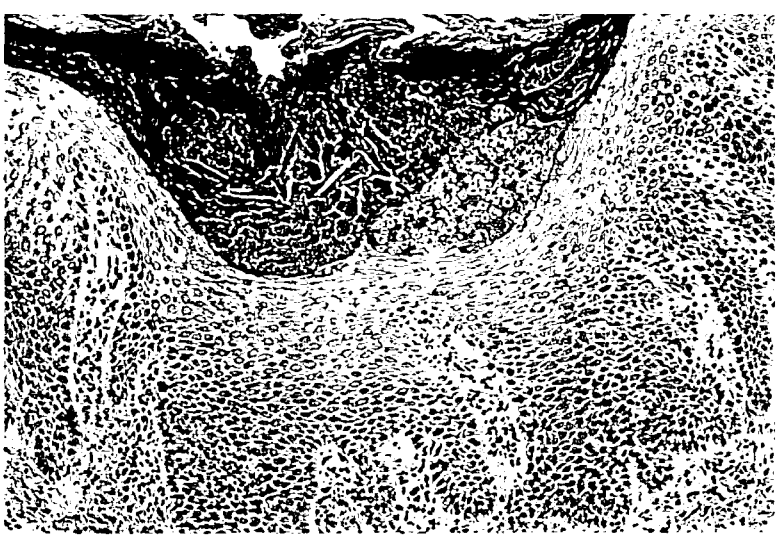

FIGURE 80–3. Black rhinoceros skin with superficial pustular dermatitis. A subcorneal pustule is present in a hyperplastic epidermis. Hematoxylin and eosin stain; original magnification. ×1000.

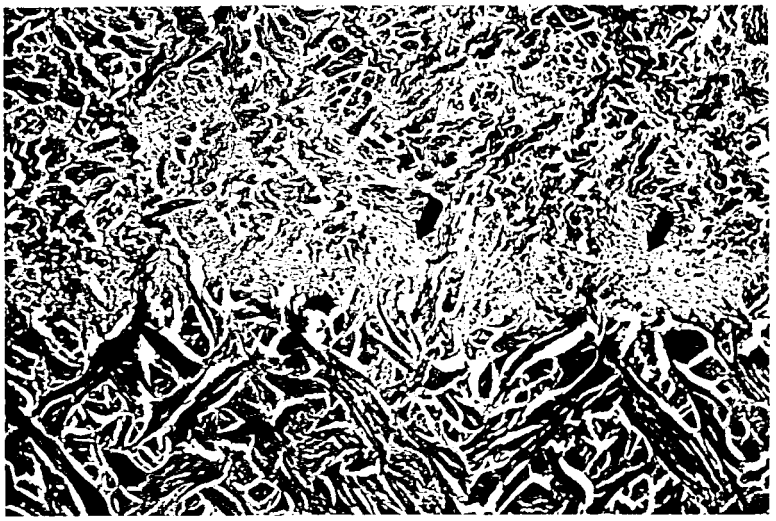

FIGURE 80–4. Black rhinoceros skin with nodular collagen degeneration. Discrete areas of degenerate and mineralized collagen in the reticular dermis are surrounded by macrophages and giant cells (*arrows*). Hematoxylin and eosin stain; original magnification, ×400.

epitheliotropic herpesvirus also has been reported in a black rhinoceros in Germany with ulcers,[8] but no herpes virus has been detected in any U.S. or wild rhinoceroses to date.

Stephanofilariasis in Wild Black Rhinoceroses

None of the aforementioned syndromes have been identified in free-ranging black rhinoceroses. However, skin ulcers associated with dermal *S. dinniki* infestations are common in southern and eastern African black rhinoceroses.[4, 7, 9, 14–16] Ulcers occur primarily on the ventral aspect of the neck and on the lateral aspect of the thorax, particularly behind the shoulder and on the back, abdomen, and forelimbs. The lesions are seasonal (occurring primarily during the summer and resolving in winter) and are markedly erythematous and pruritic,[15] in contrast to the ulcers caused by superficial necrolytic dermatopathy. Chronic ulcers from stephanofilariasis develop thick beds of granulation tissue and have marked dermal inflammatory infiltrates of eosinophils, histiocytes, inflammatory giant cells, and lymphocytes.[7, 15, 16] Stephanofilarial microfilaria and mature filarial nematodes can be identified in most lesions. Stephanofilarial dermatitis has not been identified in captive rhinoceroses, except for two cases in wild-caught rhinoceroses.[4] Transmission to other rhinoceroses in nonendemic regions is unlikely because the appropriate insect vectors[14] are not present, and anthelmintic treatments during quarantine should eliminate current infections.

REFERENCES

1. Gross TL, Ihrke PJ: Inflammatory, dysplastic, and degenerative diseases. *In* Gross TL, Ihrke PJ, Walder EJ (eds): Veterinary Dermatopathology. St. Louis, Mosby-Year Book, pp 1–326, 1992.
2. Gross TL, Song MD, Havel PJ, et al: Superficial necrolytic dermatitis (necrolytic migratory erythema) in dogs. Vet Pathol 30:75–81, 1993.
3. Grunberg W, Burtscher H: Uber eine pockenartige Krankheit beim Rhinozeros (*Diceros bicornis* L.). Zentralbl Veterinarmed Series B, Heft 6, pp 649–657, 1968.
4. Hitchins PM, Keep ME: Observations on skin lesions of the black rhinoceros (*Diceros bicornis*) in the Hluhluwe Game Reserve, Zululand. Lammergeyer 12:56–65, 1970.
5. Kasper CS: Necrolytic migratory erythema: unresolved problems in diagnosis and pathogenesis, a case report and review. Cutis 49:120–128, 1992.
6. Kasper CS, McMurry K: Necrolytic migratory erythema without glucagonoma versus canine superficial necrolytic dermatitis: is hepatic impairment a clue to pathogenesis? J Am Acad Dermatol 25:534–541, 1991.
7. Kock N, Kock MD: Skin lesions in free-ranging black rhinoceroses (*Diceros bicornis*) in Zimbabwe. J Zoo Wildl Med 21:447–452, 1990.
8. Kock RA, Garnier J: Veterinary management of three species of rhinoceroses in a zoological collection. Proceedings of an International Conference on Rhinoceros Biology and Conservation, San Diego, CA, pp 325–345, 1991.
9. Miller RE: Diseases of black rhinoceroses in captivity. Proceedings of the Symposium on Game Ranching Rhinoceroses, Onderstepoort, Republic of South Africa, University of Pretoria, pp 180–185, 1994.
10. Miller WH, Scott DW, Buerger RG, et al: Necrolytic migratory erythema in dogs: a hepatocutaneous syndrome. J Am Anim Hosp Assoc 26:573–581, 1990.
11. Munson L, Koehler JW, Wilkinson JE, et al: Vesicular and ulcerative dermatopathy resembling superficial necrolytic dermatitis in captive black rhinoceroses (*Diceros bicornis*). Vet Pathol 35:31–42, 1998.
12. Pilaski J, Schaller K, Matern K, et al: Outbreaks of pox among elephants and rhinoceroses. Verhandlungber Erkrankg Zootiere 24:257–265, 1982.
13. Pilaski J, Schaller K, Olberding P, et al: Characterization of a poxvirus isolated from white rhinoceros (*Ceratotherium s. simum*). Zentralbl Bakteriol Mikrobiol Hyg 251:440, 1982.
14. Round MC: A new species of *Stephanofilaria* in skin lesions from the black rhinoceros (*Diceros bicornis*) in Kenya. J Helminth 38:87–96, 1964.
15. Schultz KCA, Kluge EB: Dermatitis in the black rhinoceros (*Diceros bicornis*) due to filariasis. J South Afr Vet Med Assoc 31:265–269, 1960.
16. Tremlett JG: Observations on the pathology of lesions associated with *Stephanofilaria dinniki* Round 1964 from the black rhinoceros (*Diceros bicornis*). J Helminth 38:171–174, 1964.
17. Yager JA, Scott DW: The skin and appendages. *In* Jubb KVF, Kennedy PC, Palmer N (eds): Pathology of Domestic Animals, vol 1, 4th ed. New York, Academic Press, pp 531–738, 1993.

CHAPTER 81

Anesthesia of White Rhinoceroses

J. P. RAATH

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White rhinoceroses *(Ceratotherium simum)* are routinely anesthetized for marking, sample collection, translocation, and treatments.

Anesthesia of white rhinoceroses is complicated by their sensitivity to opioids; reactions include hypertension, severe respiratory depression under anesthesia, and peculiar anatomic features. As each individual animal becomes more valuable, the need for further research and refining the anesthetic process becomes more important.

THE PLANNING PHASE

Ninety percent of the anesthesia effort should go into the planning phase of the procedure. Risks incurred once a rhinoceros has been darted can be minimized by good planning. A standard checklist should include drug delivery systems, anesthetic combinations, additional drugs and emergency treatments, antidotes, general equipment, and animal monitoring equipment.

Drug Delivery Systems

To ensure deep intramuscular (IM) deposition of the drugs, it is preferable to have a robust darting system in which the drug is discharged only when the collar of the dart hits the skin. The Palmer Cap Chur powder-charged darts and the Kruger National Park (KNP) aluminum acetic acid/bicarbonate darts (see Chapter 76) are effective systems. Air-powered rifles such as the Tel-Inject or Dan-Inject systems with long needles have also been used successfully and are preferable for darting rhinoceroses in confinement. A push rod for removing darts from the barrel should be included if a rhinoceros to be darted is a different size from the one originally intended. Enough darts for the number of animals to be anesthetized, as well as extras for supplement or antidote, should be taken.

Strong needles 50 to 75 mm in length and 2 mm in diameter are recommended. If the needle opening is in front, it is suggested that the point of the needle be bent over the middle of the lumen to avoid the formation of a skin plug. A bead or collar on the needle is sufficient to prevent the darts from falling out.

Anesthetic Combinations

Many drug combinations have been used successfully in the anesthesia of white rhinoceroses. Many of the earlier drug combinations such as diethylthiambutene hydrochloride (Themalon) and 1-(1-phenylcyclohexyl)-piperidine hydrochloride (Sernyl) and scopolamine are no longer used. Drug combinations used by the Natal Parks Board of South Africa's combinations are listed in Table 81–1, and those used by the Kruger National Park (KNP) are listed in Table 81–2.

The most important goal during field anesthesia is to obtain recumbency in the shortest possible time.

Keep (1971) of the Natal Parks Board reported that although fentanyl (Janssen Pharmaceuticals) alone will anesthetize white rhinoceroses, large doses were re-

TABLE 81–1. Natal Parks Board, South Africa, Anesthetic Combinations for White Rhinoceroses

Age Group	Etorphine (mg)	Fentanyl (mg)	Hyoscine (mg)	Azaperone (mg)
Adults	3–4	—	25	—
	1–2	30	—	50–80
	3–4	—	—	50–80
Subadults	2	—	12	—
	0.5	20	—	30–40
	2	—	—	30–40
Juveniles	1	—	12	—
	0.25	12	—	15–20
	1	—	—	15–20

TABLE 81–2. Kruger National Park, South Africa, Anesthetic Combinations for White Rhinoceroses

Age Group	Etorphine (mg)	Carfentanil (mg)	Azaperone (mg)	Hyaluronidase (IU)
Adult males	5	4	50	7500
Adult females	4	3	35	7500
Subadults	3	2	20	5000
Juveniles	1.5	1	15	5000
Calves	0.5	0.5	10	3000

quired and the animals remain sensitive to noise.[8] Fentanyl was used in combination with etorphine because of fentanyl's faster action in reducing down times and preventing the animals from running too far.

In one regimen, hyoscine, a parasympatholytic drug, was included in the darts to induce temporary blindness by causing pupil dilation, with the purpose of stopping the animal sooner under free-ranging conditions. As the combinations used in Table 81–2 stop the rhinoceros in less than 4 minutes, the author does not support this practice, considering the deleterious side effects of parasympatholytic drugs.

Carfentanil (Janssen Pharmaceuticals) has been found to be slightly more potent than etorphine hydrochloride (M99, C-Vet), hence the lower dose rates.

The use of nalorphine (Lethidrone) in small doses in the dart has also been described in black rhinoceroses to counteract the respiratory depression caused by the opioids.

Xylazine (Rompun) has been used for white rhinoceros sedation and anesthesia. Dose rates of 0.48 mg/kg in combination with etorphine are suggested for free-ranging white rhinoceroses, but reluctance to stand after administration of the antidote has been noted. Excellent results have been obtained with xylazine alone at 0.25 to 0.50 mg/kg for the sedation of rhinoceroses in pens.

Under hospital or clinic conditions, rhinoceros anesthesia can be maintained with 2% isoflurane in 100% oxygen at a flow rate of 10 L per minute. For this purpose, an endotracheal tube with an inflatable cuff has to be passed, allowing an effective seal.

Additional Drugs and Emergency Treatments

All additional drugs, such as emergency drugs—for example, respiratory stimulants (Doxapram), antidotes, and antibiotics—as well as vitamin combinations and tranquilizers, must be ready and checked before darting commences. Provisions must include a complete kit to treat accidental human injection with opioids.

Antidotes

Antidotes commonly used to reverse rhinoceros anesthesia include the agonistic antagonists nalorphine and diprenorphine hydrochloride (M5050, C-Vet) and the pure antagonists naloxone (Narcan, Boots) and naltrexone.

General Equipment

Rhinoceroses, being heavy animals, are difficult to manipulate once recumbent. People handling them should always plan for the worst-case scenario and have the following necessary equipment ready:

1. Two soft cotton ropes: one long rope, approximately 30 m long, for the head and a shorter rope of 10 m for the hind foot.
2. Blindfolds and earplugs. Blindfolds can be made of towels with Velcro on the ends. Earplugs should have long strings for getting them in the rhinoceros's ears.
3. Axes. To avoid injury as the rhinoceros stands and walks, it may be necessary to remove some trees/branches around the rhinoceros before administration of the antidote.
4. Shovels. They are used to dig or fill holes on the path of a walking rhinoceros and to remove sharp stumps close to a recumbent rhinoceros.
5. Prodders. Used with discretion, they are successful in stimulating rhinoceroses to rise after administration of the partial antagonist.
6. Inflatable vehicle jacks. They have been used with great success to support rhinoceroses in lateral recumbency.
7. Two way radios: They are essential for maintaining communication between the helicopter and ground crews.

Animal Monitoring Equipment

All monitoring equipment must be in place and ready to be connected to the animal. This includes a pulse oximeter, electrocardiographic machinery, a blood pressure gauge, and a thermometer.

REQUIREMENTS FOR PHYSIOLOGIC MANIPULATIONS

Water is used to cool down rhinoceroses in extreme temperatures, and copious amounts of cold water are necessary. Oxygen supplementation can be given through a nasal catheter or endotracheal tube. It is not difficult to pass an endotracheal tube in rhinoceroses through the nose for oxygen supplementation. The diameter of this tube must be smaller than that of the

trachea, and a commercial bovine stomach tube is adequate for adult white rhinoceroses. It is preferable to attach an intravenous (IV) line by using an ear vein or the large vein on the inner front leg. IV access is useful in emergencies, especially when blood pressure falls.

Personnel Requirements

It is important to have enough trained personnel who are well informed and to whom specific tasks have been designated.

Time Management

Rhinoceros anesthesia is induced in the morning, when temperatures are cool, and at the time of year that the animals are in good condition. In the field, late afternoon darting must be limited to extreme emergencies, because unforeseen circumstances can lead to working in the dark. Rhinoceroses breed all year round, and darting of heavily pregnant animals should be avoided.

Localities

Difficulties are experienced in darting in dense bush from a vehicle, between high trees from a helicopter, and on open plains when darting on foot. Natural obstacles such as cliffs, dongas, and open water pose a threat to ataxic rhinoceroses, and the animals must be steered away from these trouble areas before darting. Accessibility of the ground crew to the rhinoceros is always an important consideration.

THE PROCEDURE

The Approach

Darting from a helicopter is preferred under free-ranging conditions because continuous visual contact is possible and the helicopter can be used to chase other rhinoceroses away from the recumbent animal. When darting is done from a helicopter, both the pilot and marksman must identify the animal. They must take time to herd the animal close to the ground crew to ensure good dart placement. To avoid dart whiplash, the helicopter flies 10 to 30 m behind the animal and at the same speed as the running rhinoceros. Once the rhinoceros is darted, it is advisable to move away and steer the animal from a distance.

When darting is done from a ground vehicle, personnel must never drive directly toward the rhinoceros; rather, they should approach it in decreasing circles. Personnel should also avoid standing on the back of a pick-up truck or breaking the outline of the vehicle, and they should try to prevent bushes from scratching the vehicle or leaving on the back of the pick-up truck loose items that can make a noise. The vehicle follows the darted animal at a distance, and if contact is lost, trackers carrying blindfolds, ropes, and a two-way radio must follow it on foot.

Although white rhinoceroses appear to be very placid, they are extremely powerful and potentially dangerous. When darting is done on foot, it is sensible to have a back-up marksman with a heavy-caliber rifle. The marksman must be sure of a down-wind approach, wear sensible bush clothing, and walk softly, although white rhinoceroses, despite extremely poor eyesight, have acute senses of smell and hearing. Rhinoceroses regularly turn towards the marksman once the dart has been fired. The marksman must therefore be in a safe position and remain immobile after darting. A safe following distance must be maintained, and the ground crew is updated by a two-way radio.

Dart Site and Angle

A well-vascularized muscle area should be selected for dart placement. The darts must be placed at right angles to the skin to avoid subcutaneous deposition of the drug. Preference is given to the gluteal region from the helicopter; the neck area is often exposed in pens.

The Ataxic Phase

It is important to maintain continuous visual contact of the rhinoceros after darting. The ataxic phase is the most likely phase for physical injury; white rhinoceroses characteristically show a reduction in speed; a shortened gait, often dragging their feet, followed by a high stepping gait; standing; and sideways movement. The head is held higher. As soon as ataxia is noticed, the following distance is increased, to avoid further stimulation, and intervention is undertaken only if the animal moves to dangerous terrain.

White rhinoceroses can be stopped toward the end of this phase by allowing them to step into a rope with one hind leg, then securing the rope between the hock joint and the foot. This rope is tied to a vehicle or tree, and the animal is stopped. A blindfold is placed over the animal's eyes, and earplugs are inserted to reduce stimulation. If ataxia has not occurred by a certain set time, it is probable that the dart has malfunctioned. A second dart containing a full dose is fired if the animal shows no reaction in 8 to 10 minutes; one-third to half the dose is given if the animal is affected but does not stop or become recumbent.

Recumbency

The rhinoceros can be assisted into recumbency by pulling on the rope on the hind foot or by pushing the body. Although rhinoceroses tolerate lateral recumbency, sternal recumbency is preferred, except for heavily pregnant females, in which the fetus may elevate the pressure on the diaphragm. A rhinoceros must not be allowed to lie with its head downhill because this will also increase the pressure on the diaphragm.

Rhinoceroses also must not lie on their back legs for extended periods of time, because this results in occlusion of the blood supply and reluctance to stand after administration of the antidote. The rhinoceros's

weight should be shifted from time to time during recumbency. White rhinoceroses sometimes do not become fully recumbent and maintain a dog-sitting position. This is safe for short periods, but because this position places all the weight on the hind legs, it should be avoided during long procedures.

The dart wound is treated immediately with an intramammary antibiotic preparation. It is good practice to insert a catheter into an ear vein to ensure a patent pathway into the blood stream for emergencies, and a saline solution or Ringer's lactate solution is administered.

Monitoring

It is important to keep good records of physiologic parameters for each use of anesthetics to build up sufficient baseline data allowing the determination of acceptable physiologic limits.

TEMPERATURE

A long thermometer is inserted deeply into the anus to ensure accurate measurement of body temperature. The temperature depends on the amount of activity beforehand, the environmental temperature, and the health status of the animal. Temperatures vary from 36° to 39.5°C during field capture operations.

White rhinoceroses are notorious for respiratory depression and ventilate poorly when anesthetized with morphine. Nalorphine, 10 to 15 mg IV, should be administered immediately, because this increases the rate and depth of respiration and improves blood gas values. Initial respiration rates can be as low as 3 to 4 per minute but should increase to 8 to 12 per minute after administration of nalorphine.

Pulse oximeters can be attached to the ear, after the superficial pigmented layers have been scraped off, or to skinfolds of the vulva or prepuce. Reflective probes can also be inserted into the nose to use the reading from the nasal septum. Arterial blood gas values can be determined from samples obtained from the inside ear artery, into which an 18- to 20-gauge catheter has been inserted.

Opioids cause a marked increase in rhinoceros blood pressure. This elevation is caused by increased activity of the sympathetic nervous system, evidenced by a sixfold increase in norepinephrine levels seen in horses anesthetized with etorphine. Blood pressure can be monitored by direct line in the inner ear artery or by placing a cuff around the tail. Mean arterial pressures in excess of 200 mm Hg have been routinely measured but are reduced after the administration of nalorphine.

Six white rhinoceroses darted with 2 mg of etorphine and 30 mg of fentanyl had a mean blood pressure of 183 ± 16 mm Hg, whereas six darted with 3 mg of etorphine and 25 mg of azaperone had a mean arterial pressure of 141 ± 24 mm Hg. A mean arterial pressure ranged between 280 and 210 mm Hg was recorded after a white rhinoceros was anesthetized with 2.8 mg of etorphine.

Although the blood pressure in the rhinoceros is high under anesthesia with etorphine, it may well be beneficial to the hypoxic animal. If the perfusion is decreased with the persisting low oxygen tension levels, it can be very dangerous. Thus the use of high doses of adrenergic antagonists is questionable. On the other hand, a blood pressure over 200 mm Hg can result in edema and rupture of small vasculature, causing pulmonary hemorrhage.

White rhinoceroses typically show muscle shivering or rising and stiffening of the front quarters. This can be reduced by intravenous supplementation with 10 to 15 mg of detomidine (Domosedan) or by administering small IV doses of benzodiazepine or buterophenone tranquilizers. A disadvantage of these tranquilizers is the reluctance of rhinoceroses to walk after the administration of small doses of nalorphine (see later discussion).

Monitoring depth of anesthesia in rhinoceroses can be difficult. Ear movement, respiration rate, and attempts to rise are indicators. Heart rates also increase as the level of anesthesia becomes lighter, but this may also be an indication of hypoxia.

Supplemental Doses

When supplemental doses are needed, they are administered via the catheter in the ear vein. They are 25% to 33% of the initial anesthetic dosage in the same ratio as administered in the initial dart. If the additional anesthetic is used, it is important to add it into calculations of the antidote dose. Boluses of ketamine after the use of opioids should be used with caution because they may lead to extended apneic phases.

Emergencies

Apnea is especially apparent during the early part of the procedure. Steps to avoid or counteract this are as follows: Insert catheters with an IV line. Administer nalorphine in increments of 15 mg IV or small doses of nalbuphine. Administer 10 to 20 ml of doxapram (Dopram) intravenously. Although doxapram has the immediate effect of increasing respiration rate, it has very limited effect on increasing oxygenation of the blood. If there is still little improvement, abort the operation and administer the full antidote, preferably a pure antagonist such as naltrexone.

Routine oxygen supplementation to anesthetized white rhinoceroses is indicated. A flow rate of 15 L of oxygen per minute must be maintained. If the animal was suffering from apnea and treatment was administered as described earlier, the blood oxygenation should also increase. Poor ventilation will further result in hypercapnia, which will improve only if the respiration rate and depth are increased.

If, in spite of oxygen supplementation, the blood gas values remain low, the flow rate of the oxygen can be increased and the doxapram dose repeated. Fifteen minutes of oxygen supplementation via an endotracheal tube increased the PO_2 level from 35% to 115% in one rhinoceros. A dramatic color change was also observed in the venous blood (personal unpublished data). Con-

tinued low blood oxygenation is an indication to end the procedure and administer the full antidote dose.

Low blood pressure can be caused by decreased heart rate, by decreased venous return, or by excessive peripheral vasodilation. Postural change usually rectifies the problem, but epinephrine is indicated at standard dose rates if this condition persists.

High blood pressure is reduced by the IV administration of nalorphine or by small doses (15 to 30 mg total dose) of a butyrophenone such as azaperone.

Rhinoceros body temperatures exceeding 39°C can be reduced by pouring copious amounts of water on the animal, combined with movement of air over the animal (fans or waving branches). Rhinoceroses can be covered with branches to protect them from direct sunlight, or large volumes of cold intravenous fluids or cold water enemas can be administered. If the temperature continues to rise, consideration should be given for anesthetic reversal.

If rhinoceroses recently drank water before darting, water may flow from their mouths during anesthesia. This condition may necessitate termination of the procedure, because inhalation of the water can lead to pneumonia. Care must be taken that the head is held lower than the body and the nose is pointing downwards.

Fortunately, white rhinoceroses do not generally awaken suddenly but will show prior warning signs. These include increased ear movements, curling of the tail, and increased heart rates. If the animal attempts to rise, a supplemental dose is indicated.

Reversal

Before reversal, all work on the rhinoceros must be completed and all monitoring equipment must be removed. All persons and vehicles are moved away from the rhinoceros, and the helicopter should be ready for take-off.

Heavy animals tend to compromise the arterial blood supply to the undermost muscles, and the venous draining can be completely occluded. This leads to an increase in lactate, which precipitates muscle spasms and reduces the blood flow even further. This can lead to difficulty in standing after a long recumbency. The weight of the animal should be shifted periodically during long recumbencies and the rhinoceros should be placed in lateral recumbency for 5 minutes before reversal. Rhinoceroses that are anesthetized in winter months, in poor condition, and when heavily pregnant take longer to rise than do others.

Diprenorphine at three times the etorphine dose and naltrexone at 40 times the etorphine or carfentanil dose are standard dose rates. If only nalorphine is available, a total of 250 mg is administered to an adult rhinoceros.

The antidote is administered via the catheter in the ear vein, and the ear plugs and blindfold are removed. Personnel should move clear of the animal to allow it to wake up alone and calmly. If a cow and a calf have been immobilized together, they should receive their antidotes simultaneously.

The agonistic antagonists nalorphine and diprenorphine can be used to partially or completely reverse the anesthesia in white rhinoceroses. Even after complete reversal dosages have been administered, the rhinoceroses remain docile and seminarcotized for up to 24 hours. Further administration of these antidotes does not improve this condition. Complete reversal occurs if the pure antagonists naloxone and naltrexone are used.

Sometimes it is not possible to place the transport crate close to the recumbent animal, because of habitat restrictions. It is possible to walk a white rhinoceros (up to a few kilometers) from the site of recumbency to more suitable terrain. The path toward the crate should be planned and cleared beforehand, and two persons walk ahead to remove obstacles that may jeopardize the walking rhinoceros. Walking rhinoceroses cannot negotiate sharp turns.

The middle of a 30-m rope is tied around the rhinoceros's blindfolded head. The two loose ends of approximately 15 m each are laid out in front of the rhinoceros, and four or five persons are placed on each rope to act as pullers. The rope on the hind foot must remain during this procedure to act as a brake.

Nalorphine is injected into the ear vein in 50-mg and 30-mg boluses for adults and subadults, respectively. These dosages must be adapted according to the level of anesthesia of the rhinoceros at the time of reversal. Of importance is that rhinoceroses that receive oxygen generally require less nalorphine to walk. Approximately 3 minutes should pass before the rhinoceros is stimulated to stand, by patting on the head or prodding the lip in order to raise the head. Determining whether it is necessary to administer a second bolus of nalorphine requires careful judgment. The head must raise first, and the two front legs must be extended. The rhinoceros is pulled forward until it is standing on all four legs. Still blindfolded, it will walk with an unstable gait and can be guided by lateral pulling and pushing on the horn. A steady pace must be maintained because stopping will result in recumbency.

If the rhinoceros starts running or becomes difficult to control, the brake rope is tied around a tree to stop the animal. Once the rhinoceros has calmed down, the walking can be continued. The full antidote and the tranquilizers can be administered once the rhinoceros is loaded in the crate.

POSTRECOVERY PHASE

Under free-ranging conditions, the rhinoceros is allowed to wander off undisturbed. The helicopter can be used to ensure that the reversed cow and her nonmanipulated calf are reunited. Where circumstances allow, subsequent monitoring from a distance is advised.

COMBINED ANESTHESIA OF COWS AND CALVES

If the cow and the calf are both to be anesthetized, they are darted in quick succession. The cow must be darted first, because the calf will remain with its mother and can often be darted while it is standing next to the recumbent cow. Success has been obtained by darting the cow and calf with a double-barrel dart gun. The

animals should be left undisturbed, allowed to remain calmly together, and become recumbent close to each other. Problems can arise if there is a dart failure with one of the animals or if they separate during the ataxic phase, which occurs most often in dense vegetation.

Therefore, sufficient ground crew to form two teams must be available when this procedure is undertaken.

CONSIDERATIONS IN DARTING RHINOCEROSES IN CONFINEMENT

The anesthesia of a rhinoceros in a pen is far more controlled. The water trough is drained and the animals are not allowed to wallow 6 hours in advance to avoid regurgitation of water during anesthesia or even drowning during the ataxic phase.

For anesthesia in a boma, 0.25 to 0.4 mg of etorphine (M99) with 10 to 20 mg of azaperone is used if a standing immobilization is required, or 1 to 1.5 mg of etorphine (M99) and 50 mg of azaperone are used if recumbency in adults is required.

To load a rhinoceros into a crate from a pen, allow 10 to 15 minutes after darting until the animal shows a high stepping gait and the tendency to follow moving objects. A white rag tied to a long stick is waved in front of the rhinoceros and slowly moved toward the crate. The rhinoceros will follow the rag with a slow and unstable gait, toward and finally into the crate. (In a similar way, rhinoceroses can be enticed to press their heads against the pen wall when a standing anesthesia is sufficient). Once the rhinoceros is crated, the tranquilizers and antidote are administered through the trapdoor in the crate's roof. During this process, sound and movement should be limited to prevent distracting the animal.

Monitoring after reversal in the pen or crate is important for the first 12 hours to ensure that no renarcotization takes place.

REFERENCES

1. Allen JL: Immobilization of Mongolian wild horses (*Equus przewalskii przewalskii*) with carfentanil and antagonism with naltrexone. J Zoo Wildl Med 23(4):422–425, 1992.
2. Dunlop CI, et al: Temporal effects of halothane and isoflurane in laterally recumbent ventilated male horses. Am J Vet Res 48(8):1250–1255, 1987.
3. Goodman AG, Gilman LS, et al: The Pharmacological Basis of Therapeutics. New York, Macmillan, pp 485–504, 1991.
4. Hall LW, Clarke KW: Hall and Clarke Veterinary Anaesthesia, 8th ed. London, Baillière Tindall, pp 215–218, 1985.
5. Hattingh J, Knox CM, Raath JP: Blood pressure and gas composition of the white rhinoceros at capture. In press.
6. Heard DJ, Olsen JH, Stover J: Cardiopulmonary changes associated with chemical immobilization and recumbency in a white rhinoceros (*Ceratotherium simum*). J Zoo Wildl Med 23(2):197–200, 1992.
7. Jaffe RS, et al: Nalbuphine antagonism of fentanyl-induced ventilatory depression: a randomized trial. Anesthesiology 68:254–260, 1988.
8. Keep ME: Etorphine hydrochloride antagonists used in the capture of the white rhinoceros, *Ceratotherium simum simum*. Lammergeyer 13:60–68, 1971.
9. Kock MD: Use of hyaluronidase and increased etorphine (M99) doses to improve induction times and reduce capture-related stress in the chemical immobilization of the free-ranging black rhinoceros (*Diceros bicornis*) in Zimbabwe. J Zoo Wildl Med 23(2):181–188, 1992.
10. Kock MD, la Grange M, du Toit R: Chemical immobilization of free-ranging black rhinoceros (*Diceros bicornis*) using combinations of etorphine (M99), fentanyl, and xylazine. J Zoo Wildl Med 21(2):155–165, 1990.
11. LeBlanc PH, Eicker SW, Curtis M, Bechler B: Hypertension following etorphine anesthesia in a rhinoceros (*Diceros simus*). J Zoo Anim Med 18(4):141–143, 1987.
12. McKenzie A: The Capture and Care Manual. Pretoria, Wildlife Decision Support Services and South African Veterinary Foundation, pp 512–528, 1993.
13. Soma LR: Equine anesthesia: Causes of reduced oxygen and increased carbon dioxide tensions. Compend Cont Ed 2(4):57–63, 1980.
14. Taylor PM: Risks of recumbency in the anaesthetised horse. Eq Vet J 16(2):77–78, 1984.