WILEY

Exotic and Wild Animal

Sampler

Feather Damaging Behavior and Self-Injurious Behavior

From *Blackwell's Five-Minute Veterinary Consult – Avian.*

by Yvonne van Zeeland and Nico Schoemaker.

Chapter 9: Hedgehogs

From *Pathology of Small Mammal Pets,* First Edition.

by Patricia V. Turner, Marina L. Brash, and Dale A. Smith.

Chapter 28: Surgery

From *Reptile Medicine and Surgery in Clinical Practice,* First Edition.

Edited by Bob Doneley, Deborah Monks, Robert Johnson, and Brendan Carmel.

FEATHER DAMAGING BEHAVIOR AND SELF-INJURIOUS BEHAVIOR

BASICS

DEFINITION
Feather damaging behavior is a condition in which the parrot mutilates its feathers with the beak and may involve chewing, biting, plucking and/or fraying. Typically, the feathers of the head and crest remain unchanged as these are inaccessible to the bird's beak. In case of self-injurious behavior or automutilation, skin damage is also present.

PATHOPHYSIOLOGY
In general, three underlying pathophysiological mechanisms should be taken into consideration for this condition:
1. *Maladaptive behavior*, resulting from attempts of the animal to cope with an abnormal or inadequate environment, which is lacking the appropriate stimuli needed and/or in which stressors are present.
2. *Malfunctional behavior*, resulting from an abnormal psychology, brain development, or neurochemistry, which may have developed as a result of the bird's living conditions, particularly in early life.
3. Abnormal behavior resulting from *underlying medical (physical) problems*. Any disease causing pain, discomfort, irritation and/or pruritus may result in the bird damaging its feathers.

SYSTEMS AFFECTED
• Behavioral—birds may spend more time on preening and/or preen more intensively, which results in damaged feathers and/or skin; other abnormal repetitive behaviors (such as stereotypic behavior) may also be seen. • Skin/Exocrine—feathers may be pulled and/or frayed resulting in generalized or patchy alopecia in areas that are accessible to the bird's beak. Covert and/or down feathers are the main target, although remiges and/or rectrices may be targeted as well. Skin damage and/or (secondary) infections may also be present.
• Endocrine/Metabolic—metabolic needs may be increased due to lack of insulation and decreased thermoregulatory abilities.
• Hemic/Lymphatic/Immune—blood loss may occur in birds with self-injurious behavior.

GENETICS
Genetic factors are thought to be involved because of species predilections. Results of a study in Amazon parrots that demonstrated high heritability estimates support the hypothesis that a genetic basis indeed exists.

INCIDENCE/PREVALENCE
Feather damaging behavior (including self-mutilation) is estimated to occur in 10–15% of captive parrots.

GEOGRAPHIC DISTRIBUTION
N/A

SIGNALMENT
• **Species predilections:** ◦ Although the condition may occur in any parrot species, Grey parrots (*Psittacus spp.*), Eclectus parrots (*Eclectus roratus*) and cockatoos (*Cacatua spp.*) appear particularly prone. ◦ The condition is less common in budgerigars (*Melopsittacus spp.*). ◦ Aside from parrots, the condition may also be seen in other bird species, including birds of prey, with the Harris hawk (*Parabuteo unicinctus*) identified as a highly susceptible species. ◦ Automutilation appears most common in cockatoos, particularly umbrella (*Cacatua alba*) and Moluccan cockatoos (*Cacatua moluccencis*). • **Mean age and range:** Although feather damaging behavior may occur at any age, it has been suggested that the age of onset lies around the time when parrots become sexually mature.
• **Predominant sex:** Feather damaging may occur both in male and female parrots, with a suggested predilection for the female gender.

SIGNS
General Comments
• The behavior is usually self-inflicted but in some cases it can be directed to cage mates or nestlings. • Severity of the disease may vary from mild or localized feather damage or alopecia to severe forms with generalized feather damage, alopecia and/or self-mutilation.

Historical Findings
• The most noticeable signs in birds with feather damaging or self-injurious behavior are the presence of featherless areas and/or skin damage. • Owners may note the bird plucking, biting or pulling its feathers or damaging its skin, but the behavior may be difficult to distinguish from normal preening and also occur when the owner is not present.
• Extensive history taking is needed to identify potential underlying medical and/or behavioral causes.

Physical Examination Findings
• Presence of featherless areas and/or damage to the feathers (fraying, chewing) and/or skin.
• Feathers are mainly plucked in the easy accessible regions of the neck, chest, flank, inner thigh and ventral wing surface; feathers of the head and crest are typically unaffected as these are inaccessible to the bird's beak.
• Contour and down feathers are usually affected, but some birds may also damage the tail and flight feathers. • A thorough physical examination (including a dermatologic and fecal examination) is needed to determine the extent of the feather and/or skin damage and identify potential underlying medical causes (e.g., ecto- or endoparasites). • In some birds with skin damage, secondary infections and/or hemorrhage may be present.

CAUSES
• Numerous causes for feather damaging and/or self-injurious behavior have been reported. Generally, however, definitive proof of causal relationships is lacking for most conditions. • The following *medical causes* have been associated with feather damaging behavior: ◦ Ecto- and endoparasites (e.g., *Knemodicoptes*, feather or quill mites, lice, *Giardia*/protozoal infection [particularly in cockatiels]). ◦ Bacterial or fungal dermatitis and/or folliculitis (including *Staphylococcus, Aspergillus, Candida, Malassezia spp.*). ◦ Viral infections such as polyomavirus, PBFD (circovirus) and poxvirus. ◦ Infectious skin and/or feather disease (bacterial, fungal, viral). ◦ Skin neoplasia (e.g., xanthoma, lipoma, squamous cell carcinoma). ◦ Nutritional deficiencies (e.g., hypovitaminosis A) and/or dietary imbalances. ◦ Low humidity levels, lack of bathing opportunities. ◦ Airborne, topical and/or ingested toxins, including cigarette smoke, scented candles, air fresheners, hand lotions and creams, heavy metal ingestion (e.g., lead, zinc). ◦ Hypersensitivity, skin allergy. ◦ Systemic diseases such as Chlamydiosis, Proventricular Dilatation Disease. ◦ Internal disease involving the respiratory tract (e.g., air sacculitis, pneumonia), liver (e.g., hepatitis), gastrointestinal (e.g., colic, gastroenteritis) or urogenital tract (e.g., renomegaly, cystic ovaries, egg binding). ◦ Endocrine and/or metabolic conditions (e.g., hypothyroidism, diabetes mellitus, hypocalcemia). ◦ Orthopedic disorders (e.g., osteosarcoma, fracture, osteomyelitis). ◦ Improper wing trim or (iatrogenic) trauma. • *Behavioral (psychogenic) causes* leading to the development of feather damaging behavior may include: ◦ Social isolation or overcrowding. ◦ Inability to perform species-specific behaviors (e.g., foraging) resulting in redirected feather damaging behavior. ◦ Small cage or poor cage design, which provides the parrot with little space to move around. ◦ Sudden changes to the environment, lack of predictability and/or controllability of the environment. ◦ Sleep deprivation, abnormal photoperiod. ◦ Boredom. ◦ (Sexual) frustration, hormonal imbalance (often cyclic or seasonal changes occurring). ◦ Stress (feather damaging behavior serves as a coping mechanism, resulting in dearousal). ◦ Anxiety, phobias. ◦ Attention seeking behavior; reinforced by responses of the owner. ◦ Abnormal repetitive behavior resulting from neurotransmitter deficiencies and/or excesses (e.g., serotonin, dopamine, endorphins), similar to obsessive-compulsive or impulsive disorders in humans.

RISK FACTORS
• Feather damaging behavior and self-injurious behavior are generally regarded

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as multifactorial disorders that may be influenced by a number of medical, genetic, neurobiologic and/or socioenvironmental factors. • Any type of disease causing pain, discomfort, irritation or pruritus may result in the bird displaying abnormal behaviors such feather damaging behavior. • Early living conditions, particularly hand rearing, inadequate socialization and deprivement, may predispose the bird to develop feather damaging behavior. • Lack of an appropriate living environment (particularly lack of foraging opportunities) and/or presence of stressors, both in early life and present living conditions, may influence the onset of abnormal behavior. • Abnormal behavior may unintentionally be reinforced by the owner, as his/her responses may be rewarding the bird. • Neurotransmitter (e.g., serotonin, dopamine, endorphin) deficiencies and/or excesses may play a role in the onset and/or maintenance of the abnormal behavior, although little is currently known about the neuropathophysiologic mechanism underlying the behavior.

DIAGNOSIS

DIFFERENTIAL DIAGNOSIS

• Feather damaging behavior should be distinguished from other causes of alopecia or feather loss including normal molt and/or apteria (not recognized by an inexperienced owner), cage mate plucking (excessive allopreening), (iatrogenic) trauma, feather loss due to parasitism or bacterial, mycotic or viral infections, and plucking related to normal brooding behavior (bird preparing a brood patch). In addition, causes for lack of feather growth (e.g., hypothyroidism, malnutrition, PBFD) should be ruled out as well. • A thorough history and physical examination (including a thorough dermatologic examination of skin and feathers) are needed to identify potential underlying causes for feather damaging or self-injurious behavior. • Before a (definite) diagnosis of feather damaging as a primary behavioral disorder can be made, the presence of underlying medical conditions disease should be ruled out (*see Causes*). • In case a psychologic or behavioral origin of the disorder is likely, effort should be made to identify the potential underlying triggers (antecedents) and reinforcing factors (consequences) that may have contributed to the onset and maintenance of FDB.

CBC/BIOCHEMISTRY/URINALYSIS

• Leukocytosis, heterophilia, and/or monocytosis may be seen in case of (secondary) infections. • In case of blood loss, hematocrit values may be decreased. • Plasma creatine kinase values may be elevated. • Dependent on the underlying cause, other abnormalities may be noted.

OTHER LABORATORY TESTS

Other laboratory tests that may be performed to diagnose or rule out any medical underlying conditions may include one or more of:
• Fecal examination (including wet mount and flotation), for example, for diagnosis of Giardiasis or other endoparasites. • PCR testing on full blood (PBFD, circovirus) or cloacal swab (Polyomavirus, avian bornavirus, *Chlamydia*). • Serology testing for avian bornavirus, *Chlamydia.* • Heavy metal screening for lead or zinc toxicosis. • TSH stimulation tests for hypothyroidism (only if feather growth is absent).

IMAGING

• Whole body radiographs may be useful to identify various underlying causes including heavy metal intoxication, reproductive disorders (e.g., egg binding), hepato-, spleno- or renomegaly, proventricular dilatation disease, pneumonia, air sacculitis, neoplastic conditions, musculoskeletal disease (e.g., osteoarthritis, osteomyelitis, fractures, osteosarcoma). • Ultrasound may be indicated to rule out or diagnose hepatomegaly, reproductive disorders (e.g., egg peritonitis, cystic ovary), neoplastic conditions, cardiac disease, ascites.

DIAGNOSTIC PROCEDURES

Additional diagnostic tests that may be useful to diagnose underlying medical conditions include:
• Cytologic examination of skin lesions (scrapings, tape strip, impression smear, swab, fine needle aspirate) or feather pulp (feather digest) to diagnose bacterial or fungal folliculitis or dermatitis, pox virus, ectoparasites (feather or quill mites, *Knemidocoptes*), neoplasia. • Culture and sensitivity of skin lesions and/or feather pulp to diagnose bacterial or fungal dermatitis or folliculitis. • Skin and/or feather follicle biopsy (histopathology) to diagnose a variety of infectious, inflammatory and/or neoplastic skin diseases, for example, PBFD, polyomavirus, bacterial and fungal folliculitis, quill mite infestation, xanthomatosis, squamous cell carcinoma, feather follicle cysts. • Intradermal skin testing to diagnose hypersensitivity reactions, allergic skin disease. Thus far these tests are, however, not found to be reliable due to the bird's diminished reaction to histamine. • Endoscopy, for example, to diagnose air sacculitis, hepato- or nephropathy, splenomegaly, pancreatic disorders, reproductive disease.

PATHOLOGIC FINDINGS

• Gross pathological finding: Patchy or generalized alopecia or feather damage with or without skin damage and/or secondary infections, with the head typically remaining unaffected. • Histopathology may help to distinguish between inflammatory and traumatic (self-inflicted) skin disease: • Inflammatory skin disease is characterized by presence of perivascular inflammation in the superficial or deep dermis of clinically affected and unaffected sites (i.e., outside of the reach of the bird's beak). • Traumatic skin disease is characterized by superficial dermal scarring with or without inflammation in the affected sites and an absence of inflammation in the unaffected sites. • In case inflammatory cells are present, these typically include lymphocytes and occasionally plasma cells, histiocytes, and granulocytes.

TREATMENT

APPROPRIATE HEALTH CARE

• Correct the diet and/or modify the bird's housing and living conditions to address any environmental factors that may be involved. • Promote a more stimulating environment by means of increasing the size of the enclosure, taking the bird outdoors, providing social contact, (chewing) toys, puzzle feeders and other forms of environmental enrichment. In particular, foraging enrichment has been shown to effectively reduce feather damaging behavior. • Training and behavior modification techniques, such as desensitization, counter-conditioning and differential reinforcement of alternate (desired) behaviors, may be employed to alter the behavior of the bird and provide the bird a mentally stimulating challenge or task. • Address medical conditions appropriately, if present. • In case of severe automutilation, mechanical barriers such as Elizabethan collars, neck braces, "ponchos", "jackets" and "vests", can be used. These, however, merely provide symptomatic treatment and may cause additional stress. • Local application of foul-tasting substances is controversial as these may sometimes result in deterioration. • In case of (secondary) skin infections, the use of appropriate antibiosis (preferably based on results of a culture and sensitivity testing) and/or NSAIDs may be considered. • Drug therapy may be warranted in cases that are refractory to treatment with enrichment and/or behavior modification (*see Medication*).

NURSING CARE

• In case of severe skin damage, wound management followed by placement of a protective wound dressing and/or "jacket" to prevent the bird from further mutilating itself is indicated. • In case of (severe) blood loss, fluid therapy and/or blood transfusions may be considered.

ACTIVITY

Promote the bird's species-specific behaviors and provide the bird with sufficient exercise and mental challenge to satiate its needs.

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DIET
• Nutrition of the bird should be optimized to correct for any potential deficiencies that may exacerbate the behavior. If fed a seed mixture, owners should be advised to convert the bird to a pelleted diet. • Provide the bird with mental and/or physical challenge by offering the food in a puzzle feeder, hiding and/or mixing it with inedible items. Larger-sized food particles and/or treats (e.g., walnuts, pine cones) may promote the bird's foraging activities as well.

CLIENT EDUCATION
• Provide the bird with adequate nutrition and a low stress, stimulating environment in which it is able to display its species-specific behaviors. • To create a stimulating environment, various types of enrichment that stimulate the bird's senses and provide a physical and mental challenge may be offered to the bird. Particularly puzzle-feeders and other types of foraging enrichment promote the bird's natural behavior and can help to satiate the behavioral need to forage. • Create awareness with the owner that he/she may (unintentionally) reinforce the behavior by paying attention to the bird when it is displaying the abnormal behavior in an attempt to distract the bird or getting it to stop plucking or biting its skin and/or feathers. • Create awareness that, once a bird is plucking or damaging its feathers and/or skin, the condition may be challenging to treat, with relapses occurring frequently.

SURGICAL CONSIDERATIONS
N/A

MEDICATIONS

DRUG(S) OF CHOICE
• In case of refractory cases, pharmacologic intervention using one of the following psychotropic agents may be considered:
◦ Dopamine antagonists, for example, haloperidol. ◦ Opiate receptor antagonists, for example, naloxone, naltrexone. ◦ Tricyclic antidepressants, for example, amitriptylline, clomipramine, doxepin. ◦ Serotonergic reuptake inhibitors, for example, fluoxetine, paroxetine. ◦ Benzodiazepines, for example, alprazolam, clonazepam, diazepam, lorazepam. ◦ Anxiolytic drugs, for example, buspirone. ◦ Hormone therapy using GnRH agonists such as leuprolide acetate and deslorelin implants may be indicated when feather damaging behavior is suspected to be sexual or hormonally related. ◦ Of the aforementioned drugs, clomipramine thus far appears the best investigated drugs. For most – if not all – others, placebo-controlled, double-blind, randomized studies concerning dosages, pharmacokinetics, toxicity and efficacy are lacking, thereby limiting the ability to make recommendations at this stage. • In case of underlying medical conditions and/or secondary infections, other types of medication may need to be given.

CONTRAINDICATIONS
N/A

PRECAUTIONS
Since limited information is available on the use of psychotropic drugs these should be used with caution and titrated carefully to effect while also monitoring closely for any adverse effects. Many of these drugs may take several weeks to take effect and should be gradually weaned off to prevent withdrawal symptoms from occurring.

POSSIBLE INTERACTIONS
Interactions between the various psychotropic drugs are common and may potentially be hazardous. Simultaneous use should, therefore, be avoided. When switching from one drug to another, the bird should first be fully weaned off of one drug prior to starting the new drug to reduce the risk of undesired side effects.

ALTERNATIVE DRUGS
N/A

FOLLOW-UP

PATIENT MONITORING
• Regular rechecks are recommended. As it may take at least 3–4 weeks for feathers to regrow once they are pulled, monthly rechecks seem appropriate, unless the condition is severe and/or worsens (in which case more frequent rechecks may be scheduled).
• During rechecks a detailed inspection of the plumage and skin condition should be made, with photographs and/or feather scoring systems aiding in monitoring any changes in the behavior as the latter are usually difficult to evaluate directly. • Owners are advised to keep a log and document when the feather damaging behavior occurs, which may help identify any underlying causes. • In case of (secondary) infections or underlying medical conditions, a CBC and/or biochemistry may be performed to monitor changes in the bird's health status. • In case psychotropic drugs are used, owners are instructed to monitor their bird carefully for potential side effects.

PREVENTION/AVOIDANCE
• Provide the bird with a stimulating, low-stress living environment and adequate nutrition. Particularly, the provision of (novel) enrichment, training and exercise (e.g., taking the bird outside for walks) may help to create and maintain a stimulating and controllable environment that allows the bird to perform its species-specific behaviors and make its own decisions, while simultaneously preventing the development of abnormal behaviors.
• Hand-rearing of young birds should be avoided as this may increase the risks of the bird developing abnormal behavior later on in life.

POSSIBLE COMPLICATIONS
• Severe feather loss may lead to a compromise of thermoregulatory abilities, and affect the bird's metabolic needs and immune system, thereby resulting in increased susceptibility to disease.
• Hemorrhage. • (Secondary) infections (particularly if skin damage is present).

EXPECTED COURSE AND PROGNOSIS
Feather damaging and self-injurious behavior are challenging conditions to treat, with recurrence and relapses commonly occurring, especially if one is unable to identify and eliminate the underlying cause. Prognosis is considered guarded, with chances of a successful outcome decreasing once the condition becomes more chronic and ritualized.

MISCELLANEOUS

ASSOCIATED CONDITIONS
Birds with feather damaging behavior may also display other forms of abnormal behavior, such as stereotypic behaviors (e.g., circling, tumbling, tongue playing, head bobbing or twirling).

AGE-RELATED FACTORS
N/A

ZOONOTIC POTENTIAL
N/A

FERTILITY/BREEDING
Since genetic factors are thought to be involved, breeding with feather damaging birds may best be avoided.

SYNONYMS
Feather picking, feather plucking, feather pulling, feather destructive behavior, pterotillomania

SEE ALSO
Appendix 7, Algorithm 12. Feather damaging behavior
Cere and skin, color changes
Circoviruses
Dermatitis
Ectoparasites
Feather disorders
Flagellate enteritis
Nutritional deficiencies
Problem behaviors

ABBREVIATIONS
PBFD—psittacine beak and feather disease

INTERNET RESOURCES
http://www.parrots.org/index.php/referencelibrary/behaviourandenviroenrich/
http://www.behaviorworks.org/
http://www.parrotenrichment.com/

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Suggested Reading
Nett, C.S., Tully, T.N. (2003). Anatomy, clinical presentation and diagnostic approach to feather-picking pet birds. *Compendium on Continuing Education for the Practicing Veterinarian*, **25**(3):206–219.
Orosz, S.E. (2006). Diagnostic work-up of suspected behavioural disorders. In: Luescher, A.U. (ed.) *Manual of Parrot Behavior*. Oxford, UK: Blackwell Publishing, pp. 195–210.
Rubinstein, J., Lightfoot, T.L. (2012). Feather loss and feather destructive behavior in pet birds. *Journal of Exotic Pet Medicine*, **21**(3):219–234.
Seibert, L.M. (2006). Feather-picking disorder in pet birds. In: Luescher, A.U. (ed.) *Manual of Parrot Behavior*. Oxford, UK: Blackwell Publishing, pp. 255–265.
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Client Education Handout available online

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Hedgehogs

9.1 Introduction

All hedgehogs are members of the subfamily Erinaceinae of the family Erinaceidae, which is comprised of 17 species in five genera. The European hedgehog, *Erinaceus europaeus*, is the best-known member of the family. This species is found throughout Britain; in northern, western, and central Europe; and in New Zealand where it was introduced in the 1890s. In the early 1900s, the European hedgehog was used considerably in research involving fundamental mechanisms of temperature control, hibernation, and reproduction, and infectious disease. The European hedgehog is not commonly kept as a pet; it is protected and its keeping is regulated in many European countries. While the European hedgehog has been exhibited in zoological parks around the world, the majority of information regarding its care and diseases derives from wildlife rehabilitation and rescue programs, particularly in the United Kingdom, where up to several thousand animals are cared for each year, and from surveys of disease in free-ranging animals.

The African hedgehog became popular as an exotic pet in North America in the 1980s, and the species is also kept as a display animal in zoological collections. Animals were initially imported from Africa, but the need for this was rapidly replaced by captive breeding. In addition, importation of African hedgehogs into the United States was banned in 1991 when it became more widely known that they can be subclinically infected with foot-and-mouth disease virus. The veterinary literature is somewhat inconsistent with regards to taxonomy; most sources refer to the pet hedgehog as *Atelerix albiventris*, also known as the African pygmy hedgehog, the white-bellied hedgehog, and the four-toed hedgehog (on the basis of its vestigial or absent hallux). Other sources state that lesser numbers of North African or Algerian hedgehogs (*A. algirus*) were also imported and were cross-bred with *A. albiventris*, creating hybrids. Ownership of pet hedgehogs is illegal in certain U.S. states, and may require a permit in others. The popularity of these animals as pets seems to have waned in North America in recent years, but has increased in Central America and Asia. In some parts of Europe, the long-eared hedgehog (*Hemiechinus auritus*) is more commonly kept as a pet.

A. albiventris is nocturnal and found naturally in a broad band across central Africa, where it inhabits a wide range of ecosystems, including grassland, savannah, scrub, and suburban gardens. The general range of body weight is 250–700 g, with males weighing more than females. The upper range of weight likely reflects obese captive animals. The life span of captive animals has been reported to range from 4–6 years, with occasional reports of up to 10 years. The average life span of 39 animals in an inbred zoo population was only 3.4 ± 1.1 years.

Although taxonomically an insectivore, *A. albiventris* is omnivorous, feeding on meat, eggs, and vegetable matter, as well as insects. These animals can digest 64–68% of dietary chitin, as compared to only 38% of fiber presented as cellulose. In captivity, hedgehogs can be maintained on a non-insect-based diet, such as commercial cat or dog food, which is high in protein and moderate in fat. Insects, earthworms, and chopped fruits and vegetables may be added. Hedgehogs are prone to obesity, regardless of diet, and, if fed primarily on unsupplemented insects, are at risk of developing metabolic bone disease as a result of low dietary calcium. Diseases seen in obligate carnivores, such as taurine or specific fatty acid deficiencies, have not been described in the African pygmy hedgehog.

A review of the literature can be confusing, as reference only to conditions in "hedgehogs" is common, without any further explanation of species or context. Diseases seen in the wild are very different than those in captive-bred animals, and it may not be appropriate to assume that disease susceptibility in the African hedgehog species parallels that in the European animal. The focus of this chapter will be on the diseases of the pet African hedgehog, considered here to be *Atelerix albiventris*, but information pertaining to other hedgehog species will be included where relevant.

Pathology of Small Mammal Pets, First Edition. Patricia V. Turner, Marina L. Brash and Dale A. Smith.

Published information on the diseases of the African pygmy hedgehog tends toward case reports of a specific disease in a small number of animals or review articles on the captive care and veterinary management of the species. Only a few publications summarize the types of disease and their prevalence in the larger hedgehog population and many of these are summaries of necropsy findings, with little related clinical information. African hedgehogs are like many small exotic mammals in that chronic conditions often present to the veterinarian in the guise of acute problems. Clinical signs are often cryptic, and generally nonspecific, including anorexia, weight loss, and reduced activity regardless of the actual disease condition. At necropsy, multiple processes are often discovered incidental to the main clinical problem. There is a very high rate of neoplasia in the captive African pygmy hedgehog and retrospective studies report neoplasia in 29%–53% of animals examined. Males and females are equally affected, other than for neoplasia of the reproductive tract, and animals frequently have more than one type of neoplasm. The incidence of neoplasia is higher in older animals, involving up to 69% of hedgehogs over 3 years of age in one study, with malignant tumors predominating. Oral squamous cell carcinoma, soft tissue sarcomas, and lymphoma are the three most common neoplastic processes in African pygmy hedgehogs.

9.2 Integument Conditions

The spines of the hedgehog are its most defining feature. The crown of the head and dorsum of the body are densely covered in thousands of smooth, unbarbed, sharply pointed spines 0.5–2 cm in length. In the African pygmy hedgehog, there is a linear spineless track 0.5 cm in width running approximately 2 cm in length cranially to caudally along the crown of the head. The natural color of the spines is brown with white ticking but hedgehog color variants exist, the most common being the white, or snowflake. The spines are modified hairs composed of keratin and have a fibrous cortex and a spongy, complex internal structure that allows them to be light and strong. Spines are predominantly in telogen and at the base they narrow just before a bulbous expansion at the follicle, which prevents them from being easily plucked. On traction the quill is more likely to break mid-shaft, and on pressure the spine will bend through the narrowed area rather than pressing into the skin of the animal. Spines are replaced individually at up to 18-month intervals. The underlying skin has a thin epidermis, a loose layer of thick, poorly vascularized fibrous dermis, and subcutaneous fat, and is without sebaceous glands. Brown fat is present and used during periods of torpor or, in some species, hibernation. The face, legs, and ventrum of the hedgehog are spine-free and, in the African pygmy hedgehog, covered in pale fur from which originates the common name of "white-bellied" hedgehog. Sweat glands and sebaceous glands are present in haired areas and on the soles of the feet. Both male and female hedgehogs have up to 10 nipples in two mammary chains. The toenails are round and highly curved.

Young hedgehogs are born with the spines underneath the dorsal skin, which is edematous and swollen. The excess fluid is absorbed within the first day of birth, allowing the spines to emerge and then stiffen. The initial spines are unpigmented, flattened, and shorter than those of the adult. A second set of spines, which more closely resembles those of the adult, emerges within 2–3 days of birth.

The hedgehog is able to roll into a ball as a protective behavior, literally tucking its entire body within an outer covering of erect spines. The hedgehog can remain in this position for hours, if necessary. Hedgehog spines are sharp and can easily scratch or puncture human skin if the animal is not properly handled. Skin punctures from spines can turn septic since hedgehogs normally roll in their own fecal material.

A wide variety of diseases of the integumentary system are seen, but the most common are mite infestation, dermatomycosis, and neoplasia. Traumatic lesions can result from entanglement of toes and limbs in carpet or other fibers or in wire caging or exercise wheels, and from interactions with other hedgehogs or other domestic animals. Hedgehogs will self-mutilate after surgery. Poor management can lead to considerable overgrowth of the toenails and to dermatitis of the feet and toes from soiled wet bedding and dirty cages (Figure 9.1A).

9.2.1 Dermatitis and Quill Loss

Clinical signs of integumentary disease include poor spine and hair condition, spine loss, excessive scaling of the skin and ear margins, and cutaneous ulceration. Examination of the skin and quills with a hand lens for ectoparasites, skin scraping and cytology, and skin or quill biopsy and histology are all useful methods in differentiating the causes of dermatitis. Cultures should also be taken for bacteria and, particularly, for dermatophytes and other fungal agents. Differential diagnoses include poor diet or husbandry, and immune, infectious, and parasitic diseases. Bacterial dermatitis caused by *Staphylococcus aureus* occurs in European hedgehogs.

9.2.2 Allergic and Immune-Mediated Dermatitis

Allergic or immune-mediated disease is seen in African pygmy hedgehogs. Microscopic examination of biopsies

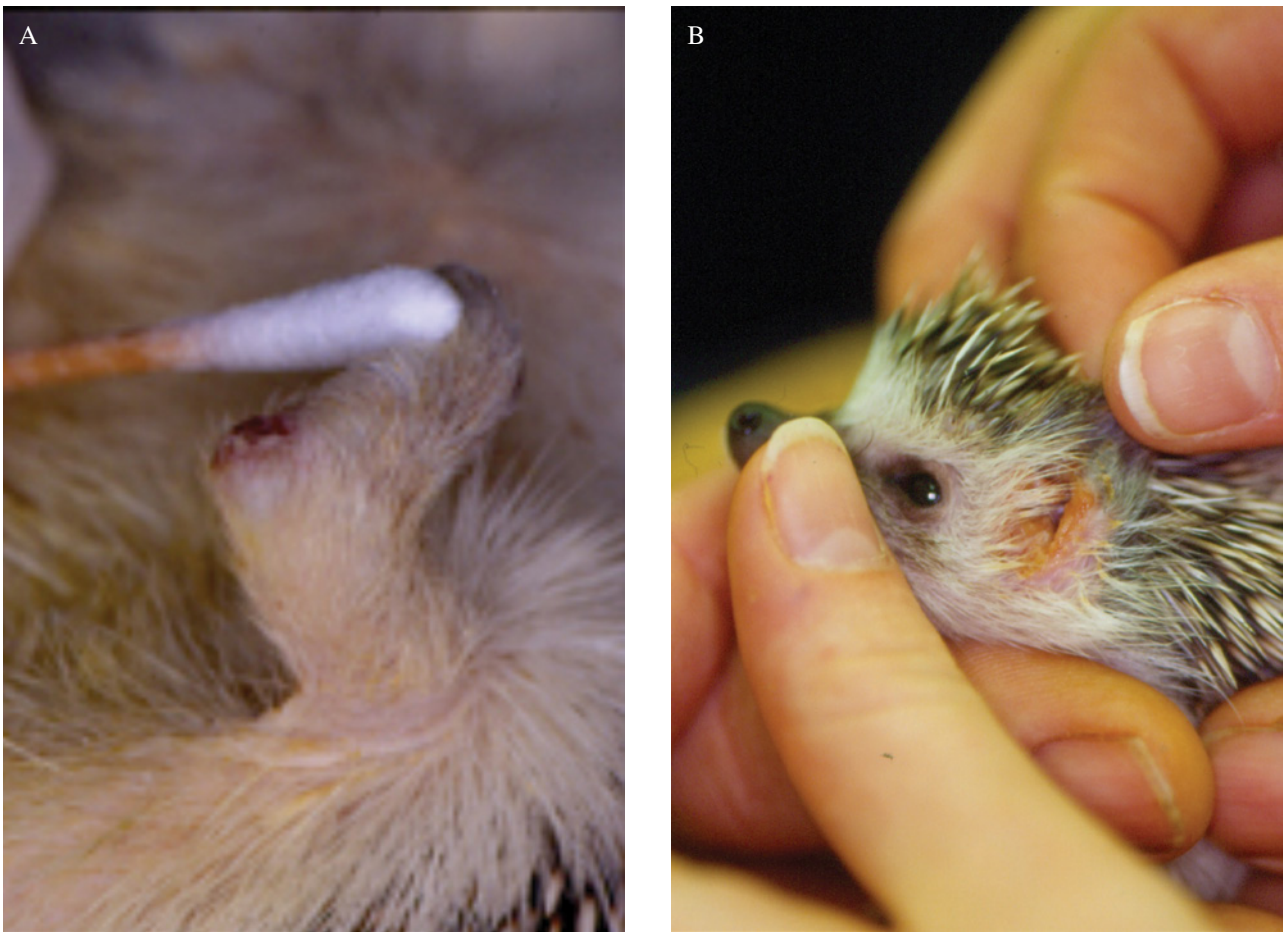

Figure 9.1 A: Pododermatitis in an African pygmy hedgehog; B: Exudative otitis externa in a hedgehog. *Source:* A and B: Courtesy of C. Wheler.

is consistent with allergic disease and lesions respond to corticosteroid treatment, but often no trigger is identified. In one report, a hedgehog developed progressive alopecia, pruritis, and facial swelling. Mild, diffuse, lymphoplasmacytic, lichenoid dermatitis with focal epithelial dysplasia and diffuse subacute dermatitis was diagnosed on a biopsy. The animal reacted to a number of items on serologic testing for allergies, and was treated with dietary change, antihistamines, and eventually glucocorticoids. Food hypersensitivity is also suspected in some cases of dermal erythema with an allergic dermatitis on the ventrum. A single case of pemphigus foliaceous-like disease has been reported in an African pygmy hedgehog. Clinical signs included dry flaking skin, loss of spines, moist inflammation on the legs, ears, chin, and anus, and epidermal collarettes on the ventral abdomen and limbs. Microscopic changes, including orthokeratotic hyperkeratosis, subcorneal pustules with eosinophils and acanthocytes in the epidermis and follicular openings, and a superficial dermatitis, were strongly suggestive of pemphigus foliaceous.

9.2.3 Otitis Externa

Otitis externa is frequently reported, with clinical signs including a purulent discharge and ear odor (see Figure 9.1B). Differential diagnoses include yeast or bacterial infection, secondary to or exacerbated by the presence of mites. Otic infestation by *Notoedres cati* has been described and occurs more commonly in European than in African pygmy hedgehogs. Clinical signs include an accumulation of waxy otic debris and pruritis; mites were identified in a smear of ear contents. Pinnal dermatitis is a non-specific finding seen in both pet and wild African pygmy hedgehogs. Affected ears have ragged edges, an accumulation of secretions along the margins, and superficial crusts. Etiologies include dermatophytosis, acariasis, nutritional deficiencies, dry skin, and non-specific seborrhea with hyperkeratosis.

9.2.4 Cutaneous Dermatophytosis

Dermatophytosis is frequently reported in wild European hedgehogs and, with increasing frequency, in pet African

pygmy hedgehogs. *Trichophyton erinacei* (previously *Trichophyton mentagrophytes* var *erinacei*) is the most common fungus identified. Observations from naturally infected hedgehogs suggest that although subclinical infection is common, lesions include a crusting and usually non-pruritic dermatitis, particularly at the edges of the pinnae, on the face, or at the base of the spines. Spine breakage and loss can occur and the skin may have a powdery or cracked appearance. The head is most frequently affected, spread to the rest of the body is slow, but there is no evidence of self-cure, and the infection is not highly transmissible. Simultaneous infection with *Caparinia tripilis* mites is common. Histologically, *T. erinacei* infection results in a neutrophilic dermal infiltrate in association with superficial exudation and hyperkeratosis. Mycelia and arthrospores can be found invading the stratum corneum between hairs, and are present in a characteristic pattern in the medullae of the spines.

There are numerous cases of human dermatophytosis resulting from contact, sometimes quite minimal, with clinically or subclinically infected hedgehogs, as well as with a contaminated environment or with dogs that have been in contact with European hedgehogs. Multiple cases of mycotic dermatitis in pet African pygmy hedgehogs and their owners have been described in Asia, Europe, and South America. In Japan, dermatophytes were cultured from 7 of 18 (39%) pet *A. albiventris*. The fungus isolated from these cases has been identified, by molecular work and mating tests, as *Arthroderma benhamiae* in teleomorph and *T. mentagrophytes* var. *erinacei* in anamorph. It was suggested that the hedgehog isolates compose a unique genotype (genotype III) that originated in Africa and was imported into Japan with the species. It is surprising that there have been no descriptions of the fungus or of zoonotic disease from North America.

Microsporum sp. has also been found in both species of hedgehog.

9.2.5 Other Causes of Mycotic Dermatitis

Several single case reports describe other causes of mycotic dermatitis in African pygmy hedgehogs. Infection by *Paecilomyces variotii* in an otherwise healthy 3-month-old African pygmy hedgehog resulted in a non-pruritic hyperkeratosis on one side of its face; the hair and quills in the area could easily be epilated. *Paecilomyces* species are saprophytic filamentous fungi that rarely cause disease in animals. The same authors described a 1-year-old hedgehog with a 3-week history of a well-circumscribed area of alopecia, scaling, and pinpoint hemorrhages on its back. Scrapings of the lesion revealed septate hyphae and, on culture, conidial heads resembling those of an *Aspergillus* sp. were present. Gene sequencing confirmed the organism to be *Neosartorya hiratsukae*, a rare opportunistic pathogen in immunocompromised humans that had not been previously described from a natural infection in an animal.

9.2.6 External Parasites

9.2.6.1 Acariasis

Acariasis is very common in pet African pygmy hedgehogs and clinical signs include erythema, pruritis, excessive flaking and crusting of the skin, and quill loss. The pinnae and face are most often affected, followed by the back, and then the ventrum. Self-trauma, secondary bacterial infection, and mortality can result. Diagnosis is made by microscopic examination of scrapings or superficial debris (Figure 9.2). A *Caparinia* sp. psoroptid mite (*C. tripilis*) is often responsible. Mites from African pygmy hedgehogs have also been identified as *Chorioptes* sp. It is likely that *Caparinia* mites were misidentified as *Chorioptes,* which they resemble. These mites are not considered to be transmissible to humans.

In one case, dermatitis resulted from a dual infection by *Notoedres cati* and *Trichophyton erinacei* in a captive-bred African pygmy hedgehog. Thick, hard, yellow and white crusts were present on the head, ears, carpus, and footpads. The mite was identified on the basis of its morphology; no source of infection was found. Treatment with antiparasitic and antifungal medications resolved the lesions. Both these infectious agents can cause zoonotic disease. *Ornithonyssus bacoti*, the tropical rat mite, is associated with flaky skin and quill loss in African pygmy hedgehogs. This mite can affect a variety of species, including humans.

Sarcoptes scabiei has been reported in *Atelerix albiventris* in West Africa.

9.2.6.2 Other Ectoparasites

Ectoparasites other than mites are not common on pet African pygmy hedgehogs. These animals may act as transient hosts for fleas of other species, but do not appear to become colonized by the fleas of dogs or cats.

9.2.7 Foot and Mouth Disease

African hedgehogs are susceptible to infection by the foot and mouth disease virus, and can be subclinically affected, spreading the disease to cattle. This resulted in a ban on their importation into the United States in 1991.

9.2.8 Nodular and Neoplastic Conditions

Nodular lesions can result from infection and abscessation, and nodular or ulcerative lesions from neoplasia. Fine needle aspiration followed by cytology or excisional biopsy and histopathology, combined with culture for infectious agents, is necessary for a specific diagnosis. Mycobacterial

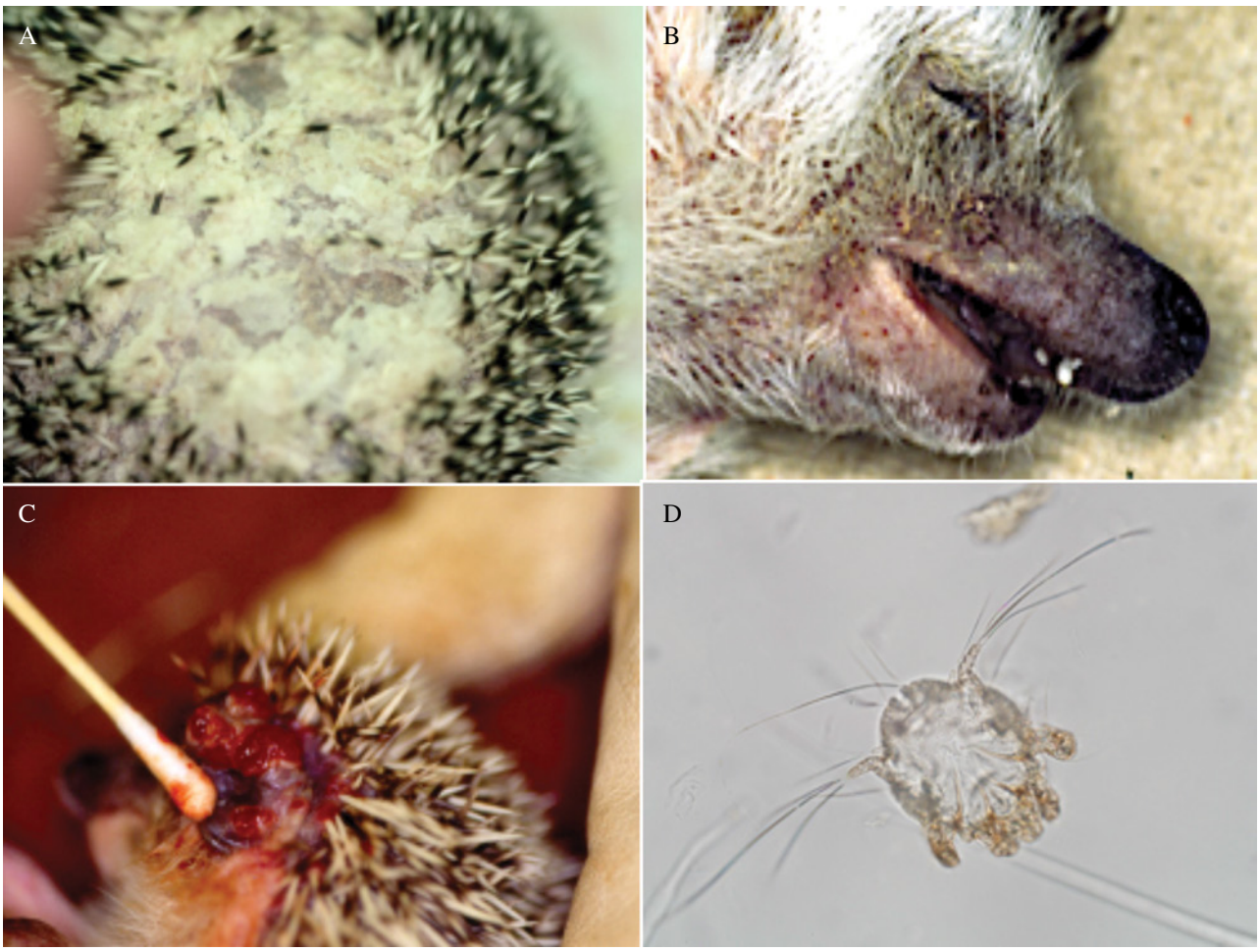

Figure 9.2 Skin and quill lesions associated with infestation by *Caparinia tripilis* (mange). A: Severe infestation on the ventrum. B: Facial mange. C: Ear infestation with eosinophilic granuloma formation. D: *Caparinia tripilis* mite from skin scraping. *Source:* A: and C: Courtesy of C. Wheler.

infection (*M. marinum*) has been described in a captive European hedgehog with granulomatous subcutaneous nodules and lymphadenitis.

In terms of neoplastic cutaneous lesions, papillomas, squamous cell carcinoma, epitheliotrophic lymphoma, mast cell tumors, sebaceous gland carcinomas, hemangiosarcoma, various stromal tumors, and mammary gland tumors are all reported.

9.2.8.1 Cutaneous Papillomatosis

Cutaneous papillomatosis is seen in African pygmy hedgehogs, with lesions ranging from single nodules to widely disseminated masses over most of the integument. A viral etiology has been proposed, but microscopic lesions have not been described.

9.2.8.2 Squamous Cell Carcinoma

Squamous cell carcinomas of the skin are seen sporadically. In one animal, severe abscessation and necrosis of the abdominal skin and underlying musculature at the junction of the quilled and non-quilled areas were associated with the presence of a squamous cell carcinoma. Generalized cutaneous squamous cell carcinoma was diagnosed on biopsy and necropsy of a 5 year-old male African pygmy hedgehog with a four-year history of dermatitis poorly responsive to a variety of treatments administered over a two-year period. Gram-negative bacterial infection, *Caparinia* sp. mite infestation, and *Trichophyton* sp. dermatophytosis had all been diagnosed clinically. See also Section 9.7.2.

9.2.8.3 Sebaceous Gland Carcinomas

Sebaceous gland carcinomas are diagnosed sporadically, and pulmonary metastases have been reported. A recurring highly aggressive sebaceous carcinoma was present in a 1.5 year-old male. The initial firm, non-movable, subcutaneous lesion, located on the ventral chest area, was surgically removed. On cut section, the mass oozed

purulent exudate from necrotic areas and infiltrated adjacent soft tissue. On microscopic examination, the tumor was unencapsulated and composed of neoplastic cells with distinct borders and abundant vacuolated cytoplasm forming trabeculae and lobules. Nuclei were large and pleomorphic with 1–3 prominent nucleoli; there were high numbers of sometimes atypical mitotic figures. Immunohistochemistry was used to make the final diagnosis. Three months after surgery the neoplasm recurred and the animal was euthanized.

9.2.8.4 Mast Cell Tumor

Cutaneous mast cell tumors occur sporadically in hedgehogs and are generally benign, although one invasive mast cell tumor has been reported. Tumors can be single or multiple, and are often present on the head, neck, or axilla. Metachromatic granules and accompanying eosinophils are characteristic features, as in other species. Mast cell tumors of hedgehogs have been described as most closely resembling the canine grade 2 mast cell tumor.

9.2.8.5 Hemangiosarcoma

Cutaneous hemangiosarcoma is seen sporadically in African pygmy hedgehogs. One report details a poorly differentiated epithelioid variant hemangiosarcoma in the skin of a 4 year-old female African pygmy hedgehog. A cutaneous mass initially appeared after trauma, was surgically removed, and reoccurred approximately 7 months later, at which time the animal was euthanized. At necropsy the mass was large, multilobulated and exophytic with ulcerated areas. It was regionally dark red to black. On microscopic examination, the mass was composed of neoplastic endothelial cells lining serpiginous vascular channels. These cells were positive for factor VIII-related antigen on immunohistochemistry. Neoplastic foci were also present in lung, liver, and kidney.

9.2.8.6 Cutaneous Stromal Tumors

Cutaneous stromal tumors seen in hedgehogs, include lipoma, fibroma and fibrosarcoma, soft tissue sarcoma, and myxoma and myxosarcoma. While invasive, these tumors are slow to metastasize.

There are several reports of malignant peripheral nerve sheath tumors. One report describes cutaneous stromal tumors from two female African pygmy hedgehogs with consistent microscopic features. The identity of the neoplastic masses was investigated using histology, immunohistochemistry, and electron microscopy. A second case report describes the surgical amputation of the forelimb of a 6 year-old African pygmy hedgehog as a result of the presence of a mass on the lateral aspect of the shoulder. Cytology was consistent with the diagnosis of a sarcoma, although moderate numbers of eosinophils and mast cells were also present. The mass was initially biopsied, and the presence of infiltrative pleomorphic neoplastic cells resulted in a diagnosis of poorly differentiated soft tissue sarcoma, likely a peripheral nerve sheath tumor. A peripheral nerve sheath tumor was also diagnosed in a 3 year-old female African pygmy hedgehog with a raised, red skin lump, which had been increasing in size for 3 weeks. Microscopic examination of the excised mass showed the dermis was expanded by a well-circumscribed, non-encapsulated mass of spindle cells arranged in short, interlacing bundles that were randomly oriented (neuroid differentiation). The mass was limited to the dermis, and the underlying panniculus was not affected. Nuclei were euchromatic, with small nucleoli, marked anisokaryosis, and there were 1–2 mitotic figures/400x field.

9.2.8.7 Mammary Gland Conditions

Mammary gland neoplasia is frequently seen in African pygmy hedgehogs. Tumors can be single subcutaneous nodules or multiple masses, and are more often malignant than benign. Metastasis to lymph nodes can occur. In one survey of biopsy tissue from eight reproductively active female hedgehogs, there was one papillary adenoma and eight carcinomas: one papillary, two tubular, and four solid. In three cases there was invasion of lymphatics, and in one of these where additional tissue was available, actual lymph node metastasis. Cases of primary inflammatory disease are rare, with one mammary gland abscess listed in a review of husbandry and reproduction of the African pygmy hedgehog.

9.3 Endocrine Conditions

9.3.1 Adrenal Gland Neoplasia

Unilateral adrenal cortical carcinomas have been described in several African pygmy hedgehogs. In most cases, clinical signs were associated with other intercurrent problems and there was no evidence of endocrine-related disease. In one case; however, clinical signs included alopecia, pendulous abdomen, polyuria, polydypsia, and polyphagia. On gross examination the tumors were large and in two animals there was seeding of the peritoneal serosa, liver, spleen and lung, sometimes accompanied by a serosanguinous effusion. The neoplasms were multilobulated with neoplastic cells arranged in cords and perivascular rosettes with a fine fibrovascular stroma. Cells were round to polyhedral with pale basophilic or eosinophilic cytoplasm, large round or indented nuclei, and mild nuclear pleomorphism and anisokaryosis. Mitotic figures were rare in two cases and common in the third.

Pheochromocytomas have rarely been reported in African pygmy hedgehogs.

9.3.2 Neoplasia of the Endocrine Pancreas

Three islet cell tumors have been reported; however, endocrine-associated clinical disease was not seen in two cases where clinical information was provided. A 4 year-old male African pygmy hedgehog had multiple fibrinous adhesions between the liver, omentum, peritoneum, and a 3-cm, dark red, friable neoplastic mass located at the hepatic hilus. On microscopic examination, the neoplastic cells were polyhedral, and arranged in cords and ribbons separated by fine fibrous stroma and there was local extension into the liver with a final diagnosis of pancreatic islet cell carcinoma.

9.3.3 Neoplasia of the Parathyroid Gland

A parathyroid adenoma was identified as an incidental finding in a 3 year-old female African pygmy hedgehog with multiple other pathologic processes, including a thyroid follicular adenoma and multicentric skeletal sarcomas associated with a retroviral infection.

9.3.4 Neoplasia of the Thyroid Gland

A unilateral thyroid adenocarcinoma was described in an adult African pygmy hedgehog. The tumor enlarged and effaced the gland. Clinical signs were referable to cellulitis in the associated cervical area; there was no evidence of tumor-associated endocrine disease. Bilateral thyroid adenocarcinoma with multiple organ metastasis has been diagnosed in a 3 year-old African pygmy hedgehog. Additional thyroid neoplasms reported as incidental findings include a thyroid follicular carcinoma and a thyroid follicular adenoma.

A parafollicular C-cell tumor was described in a 3 year-old male African pygmy hedgehog with a clinical history of dysphagia, weight loss, and tetraparesis. On gross examination, there was a palpable mass on the ventral neck. The thyroid gland was replaced by infiltrating neoplastic cells forming lobules separated by fine fibrovascular stroma. The diagnosis was based on consistent histology, intracytoplasmic staining for neuron-specific enolase, and the electron microscopic appearance of the tumor cells, including the presence of numerous neurosecretory granules. Two other C-cell carcinomas are reported in African pygmy hedgehogs.

9.4 Respiratory Conditions

Clinical signs of respiratory infection reported in hedgehogs include nasal discharge, sneezing, epistaxis, rhinitis, increased respiratory noise, dyspnea, lethargy, and inappetence. Death may occur acutely or after a period of clinical illness.

Suboptimal environmental temperature is suggested as a predisposing factor to respiratory infection through reduced immune function, and cedar shavings are likely a respiratory irritant, as in other species.

9.4.1 Bacterial Pneumonia

Pneumonia is a common disease of African pygmy hedgehogs. In one case of necrosuppurative bronchopneumonia with pulmonary abscesses and suppurative pericarditis and myocarditis in a young African pygmy hedgehog, *Corynebacterium* sp. was isolated. Other bacteria important in respiratory infections of hedgehogs include *Pasteurella* spp. and *Bordetella bronchiseptica*. *B. bronchiseptica* was associated with contagious catarrhal rhinitis and bronchopneumonia in one colony of captive hedgehogs (species not stated). Clinical signs included purulent nasal discharge, sneezing, and dyspnea.

9.4.2 Respiratory Parasites

The only report of parasitic infection of the respiratory system in the African pygmy hedgehog is the presence of *Armillifer* (a pentastome) larvae.

9.4.3 Respiratory Neoplasia

Neoplasms of the respiratory system of the African pygmy hedgehog are infrequent. Pulmonary carcinomas and adenocarcinomas are rarely described. A pulmonary adenoma was found incidentally during necropsy of a 2 year-old male African hedgehog.

9.4.4 Other Causes of Respiratory Disease

Viral causes of respiratory disease are largely unknown for African pygmy hedgehogs. Mycotic pulmonary disease also appears rare. Granulomatous pneumonia with intralesional *Aspergillus* sp. and associated mediastinal lymphadenitis was described in 7 of 98 wild European hedgehogs that were culled in New Zealand.

Chronic interstitial pneumonia, consistent with exposure to toxic fumes or gases, was described in an 18 month-old African pygmy hedgehog that was euthanized due to mite infestation. Microscopic lesions included alveolar hyaline membranes, type II pneumocyte hyperplasia, syncytial cell formation, and occasional hemosiderin-laden macrophages.

A 5 year-old male hedgehog was diagnosed with severe, acute fibrinous pneumonia due to aspiration of a small fragment of bone with subsequent mixed bacterial infection.

Hemothorax can occur as a result of trauma to the anterior vena cava, a common venipuncture site.

9.5 Musculoskeletal Conditions

The skeleton of the hedgehog is generally unremarkable, with the exception of a short tail and neck. *Atelerix albiventris* lacks a hallus and thus has only four toes on its hind foot, unlike all other members of the family Erinaceidae that have five. There are five toes on the front foot. The tibia and fibula are united distally. The age of a hedgehog can be determined by counting the number of periosteal growth lines in a decalcified section of the mandible taken at the level of the last molar tooth.

9.5.1 Trauma

Traumatic lesions, including skeletal fracture, are most frequently the result of falls, entanglement in cage wire or wire running wheels, or fighting with another hedgehog. Osteomyelitis, myositis, and cellulitis can result from injury and subsequent infection.

9.5.2 Degenerative Lesions

Osteoarthritis and intervertebral disc disease resulting in spinal cord compression are seen infrequently (see Section 9.9). A mandibular bone cyst has been described in one animal, consisting of reactive chondro-osseous tissue intermingled with connective tissue, at the center of which was necrotic bone. Differential diagnoses for the cyst included trauma, infection, and neoplasia. Vertebral spondylosis is common in older animals.

9.5.3 Metabolic Bone Disease

Invertebrates contain little calcium, thus animals fed on a largely insect diet can develop metabolic bone disease. Feeding a broader range of foodstuffs and calcium supplementation is required to prevent this condition.

9.5.4 Musculoskeletal Neoplasia

One case of a disseminated rhabdomyosarcoma is reported from an African pygmy hedgehog.

Several cases of osteosarcoma have been seen in African pygmy hedgehogs. Affected animals ranged from 2–5 years of age and tumors were found on the ribs, vertebral column, mandible, hind leg, and extraskeletal sites. Tumors have characteristics as seen in other cases of mammalian osteosarcoma.

Parosteal sarcomas have been described in two 3-year-old sibling hedgehogs, a male and a female. Clinical signs in the male included anorexia, incoordination, weakness, and diarrhea. Firm swellings were palpable over the maxilla, and radiographs revealed exostoses there and in multiple other locations. The animal was euthanized and at necropsy multiple hard bony swellings were identified on the zygomatic arch, maxilla, ribs, and lumbar vertebrae. The female died several weeks after surgery to remove an abnormal uterus. Similar gross lesions were present on the ribs, including the costochondral junctions. Microscopically, the tumors were composed of nodules of spindle cells with an outer periosteum-like layer. Cells showed chondroid and osteogenic differentiation with areas of mineralization and varying degrees of anaplasia. Large numbers of enveloped viral particles morphologically similar to type-C retroviruses were identified in neoplastic tissue from both animals. There are similarities between these cases and the retrovirus-induced feline osteochondromatosis associated with feline leukemia virus (FeLV) infection; however, immunoperoxidase staining for FeLV in the male was negative.

A chondroma with osseous differentiation of the ribs was diagnosed in a 3 year-old female African pygmy hedgehog that had experienced unilateral hind leg lameness, which progressed to bilateral hind leg paresis 2 weeks later. The tumor was present adjacent to the vertebral column, and in focal intercostal spaces. Microscopically, the mass was well delineated, and contiguous with the periosteum of the ribs. It bulged into the vertebral space, severely compressing the spinal cord but remaining extradural. It consisted of a central core of dense, partially necrotic lamellar bone surrounded by trabeculae of variably differentiated woven bone and lakes of poorly differentiated cartilage. The bone trabeculae were lined by numerous well-differentiated osteoblasts. At the site of compression, the right spinal ganglion and the right side of the spinal cord were displaced and had collapsed but had no significant morphological changes.

A soft tissue mass associated with severe lysis of the tibia and fibula in an adult male African pygmy hedgehog was diagnosed as an anaplastic fibrosarcoma. The affected leg had been amputated, but there was no follow-up on the case.

9.6 Gastrointestinal Conditions

Hedgehogs have broad skulls with muscular attachments on the pronounced cheek bones arranged to facilitate shearing. Hedgehogs are brachydont, i.e., have closed rooted teeth, and the dental formula is 2(I 3/2, C 1/1, P 3/2, M 3/3) for a total of 36 teeth. Dental variation in African pygmy hedgehogs kept as pets likely exists, but has not been frequently described. The upper first incisors are long, project slightly forward, and are widely spaced leaving a gap into which the mandibular first incisors can fit. This is considered useful in capturing and spearing insects. The deciduous teeth erupt at approximately 3 weeks of age, and are without molars. They are

replaced by permanent dentition at between 7–9 weeks of age.

Hedgehogs have a simple stomach and can vomit. They have no cecum; the small intestine is continuous with the simple colon. Gastrointestinal transit time is approximately 12–16 hours. Droppings vary from soft to pellet-like. Hedgehogs do not rely on hindgut bacterial fermentation and thus do not show antibiotic sensitivities, as do rabbits and many rodents.

Clinical signs of gastrointestinal disease are similar to those in other species and are often non-specific.

Hedgehogs can ingest foreign bodies, particularly hair, carpet fibres, and rubber. Intestinal accidents such as torsion can occur. There is one report of gastroesophageal intussusception associated with megaesophagus and severe esophagitis and esophageal ulceration in a 3 month-old African pygmy hedgehog. Congenital megaesophagus was considered likely; the most significant clinical sign was vomiting.

9.6.1 Oral Conditions

9.6.1.1 Dental Disease

Tartar accumulation, gingivitis, periodontitis, gingival recession, fractured and loose teeth, excessive wear of the teeth, and dental abscesses are all common. Feeding dry food and hard-bodied insects is felt to help in the prevention of these conditions. Food objects, such as nuts and grains, can wedge between the teeth or against the hard palate. One case of mandibular osteomyelitis and severe local cellulitis resulting from infection by *Actinomyces naeslundii*, presumed to have originated from the oral flora, is described in an adult African pygmy hedgehog. The animal died, despite a period of antibiotic treatment, and at necropsy had severe pyogranulomatous lesions containing characteristic colonies of clumped, elongate bacilli present in the mandible and surrounding soft tissues, and in the lung. Acute interstitial pneumonia, and suppurative and lymphocytic inflammation in the heart, kidneys, and liver were also present, leading to a diagnosis of death due to systemic bacterial infection.

9.6.2 Neoplasia of the Oral Cavity

Oral squamous cell carcinomas are relatively common and are usually invasive to soft tissue and bone; however, metastases to lung or regional lymph node have been seen in a few cases (Figure 9.3). Clinical signs can mimic those of dental disease and associated epithelial hyperplasia, inflammation, and osteomyelitis, but in more advanced cases marked local swelling, oral ulceration, bone destruction, and extension into the nasal cavity and sinuses can occur. Histologic and cytologic findings are characteristic of squamous cell carcinomas of other mammals.

An oral papilloma was diagnosed from a biopsy in a 4-year-old male African hedgehog. The mass was a papillary structure covered by well-differentiated keratinizing stratified squamous epithelium exhibiting pseudocarcinomatous hyperplasia. Occasional foci of hydropic and vacuolar epithelial degeneration affected the superficial epithelial layers. There was approximately one mitotic figure per high power field in the stratum basale and only occasionally in the stratum spinosum. Another gingival biopsy in a 3 year-old female African hedgehog was diagnosed as an acanthomatous ameloblastoma (acanthomatous epulis) with pyogranulomatous gingivitis. Hyperplastic epithelium was seen in cords and projections throughout the mass, with spongiosis and prominent intercellular bridges within the cords, bordered by pallisading cuboidal to columnar epithelial cells. Between the resulting islands was a fine fibrovascular stroma, with a mixed inflammatory cell population.

An invasive oral fibrosarcoma was reported in a 5 year-old African pygmy hedgehog.

9.6.3 Salivary Gland Conditions

One case of a salivary carcinoma and one case of a mucoepidermoid carcinoma of the parotid gland, with extension to the neck, have been reported in African pygmy hedgehogs.

9.6.4 Enteric Salmonellosis

Although salmonellosis is listed in the reviews of diseases of *Atelerix albiventris*, actual case reports and surveys of disease refer to the European hedgehog. The prominent exceptions to this are two Centers for Disease Control reports of human salmonellosis in association with direct or indirect contact with pet African pygmy hedgehogs in North America. In 1994, *S.* Tilene was first isolated in the United States from a 10 month-old girl with enteritis. The family of the patient raised African pygmy hedgehogs. The same organism was isolated from the feces of one of three hedgehogs sampled from the household. Since then at least 11 additional cases have been described in the United States and Canada. The majority of affected individuals have been young children. All except two cases were associated with ownership or handling of hedgehogs, particularly breeding herds. In several instances the affected person did not directly handle the hedgehog, but other family members did. In 2011–2013, an outbreak of an unusual subtype of *S.* Typhimurium affected 26 people; eight were hospitalized and one died. Investigation revealed contact with apparently healthy hedgehogs in 20/25 people, and the same outbreak strain was isolated from hedgehogs in the homes of affected individuals. No single source of

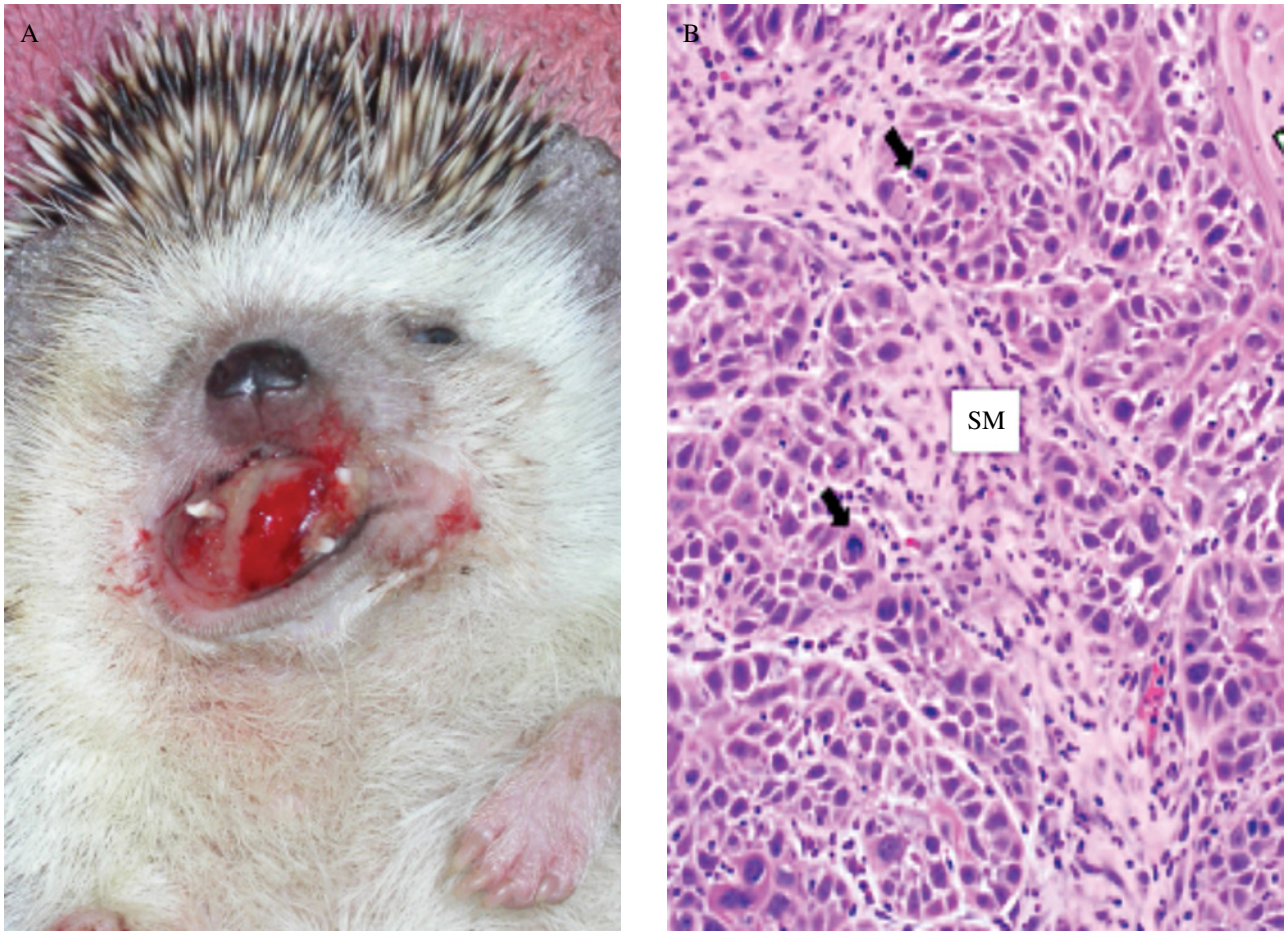

Figure 9.3 A: Oral squamous cell carcinoma with gingival proliferation, incisor malalignment, and mucosal ulceration. B: Oral squamous cell carcinoma invading underlying submucosa (SM), which contains many inflammatory cells. Keratinization, keratin pearl formation, and mitotic figures (black arrows) are present. *Source:* A: Courtesy of The Links Road Animal and Bird Clinic.

animals was identified. The extent of infection of African pygmy hedgehogs with other species of *Salmonella* is unknown.

9.6.5 Other Enteric Infectious Conditions

Diarrhea can result in African pygmy hedgehogs following dietary indiscretion, and has been reported to occur with the feeding of milk and bread.

Candida albicans was identified by cytology and culture from the feces of an African pygmy hedgehog whose clinical signs included weight loss, depression, and melena. Malnourishment was thought to be a predisposing factor.

Infection with *Mycobacterium marinum, M. avium* type 2, and *M. avium intracellulare* have been reported in European hedgehogs. *M. avium* type 2 has been cultured from the mesenteric lymph nodes of apparently healthy wild animals. Severe granulomatous facial and otic dermatitis due to *M. marinum* occurred in an adult animal that originated from a pet store but was held in a zoo. The hedgehog died after a prolonged clinical course, and, at necropsy, mycobacteriosis was diagnosed in the skin lesions, lymph nodes, and lung. It was hypothesized that the bacterium had been acquired from a fish tank in which the animal had been held in the pet store. *M. marinum* had not been previously identified as a cause of disease in a homeothermic vertebrate; the lower body temperature of the hedgehog may have facilitated infection.

9.6.6 Enteric Parasitism

It is difficult to find reports of any enteric parasites of African pygmy hedgehogs. Species of nematodes, cestodes, and protozoa likely occur in wild *Atelerix albiventris*; however, few seem to have survived the transition to domestically bred animals. Stronglyoides-type eggs were identified in the feces of two animals imported from Africa which had blood-stained diarrhea, but no adult nematodes were identified at necropsy. Spirurid-type

nematodes were identified in the stomachs of these animals, numbering from few to many.

A single case of cryptosporidiosis is described in a neonatal African pygmy hedgehog in a zoo. The diagnosis was based on histopathology; the animal had shown no clinical signs prior to death. The entire intestinal tract was filled with clear fluid and organisms were present in the jejunum, where up to 75% of the epithelial cells were affected, and in the ileum and colon. Villous atrophy and mucosal hyperplasia were present in the affected small intestine and colon, respectively. A commercial fluorescent diagnostic test for the detection of *C. parvum* was strongly positive; however, cross-reactions with other mammalian cryptosporidia occurred, thus the zoonotic potential of the infection could not be confirmed.

9.6.7 Gastrointestinal Neoplasia

Lymphosarcoma is the most common neoplastic process in the gastrointestinal tract of the African pygmy hedgehog. One case of a colonic plasmacytoma has also been described (see Hematopoietic and Lymphoid Conditions). Single reports are published for gastric, small intestinal, and colonic adenocarcinoma, and intestinal neuroendocrine tumor. The gastric carcinoma occurred in a 4 year-old male with clinical signs including respiratory difficulty, hematuria, and hematochezia. At necropsy, there was extensive metastasis to the lung with the replacement of entire lobes, as well as to the liver, spleen, and pancreas.

9.6.8 Hepatic Lipidosis

Hepatic lipidosis is an extremely common finding in African pygmy hedgehogs and may accompany a range of other disease processes or simply reflect inanition in a species that is frequently obese. Icterus may also be present, and is most easily noted in the skin of the inguinal area.

9.6.9 Herpesvirus Hepatitis

Hepatitis associated with herpes simplex virus infection has been described in one African pygmy hedgehog. The animal was placed on corticosteroid therapy for a prolapsed intervertebral disc, but two weeks later became anorectic and died. On gross post-mortem examination, there were multiple pale foci which, microscopically, correlated to areas of necrosis with neutrophils and cellular debris at the periphery. Eosinophilic intranuclear inclusion bodies with marginated chromatin were present in many hepatocytes adjacent to the lesions, and there were also syncytial cells. Immunohistochemistry and virus isolation confirmed the presence of a herpes simplex virus type 1. Members of the owner's family periodically suffered from cold sores, and this was assumed to be the source of the infection.

9.6.10 Other Hepatic Conditions

Degenerative and proliferative lesions such as periportal hepatitis, bile duct hyperplasia, and fibrosis/cirrhosis can occur. Cirrhosis is commonly seen in association with hepatic lipidosis. The use of cedar chips or scented bedding has been described anecdotally as being associated with liver disease. Iron accumulation in the liver (and spleen) in association with other disease processes has been described.

Primary and metastatic neoplasias occur in the liver but prevalence estimates and pathology are not well detailed. Single cases, each of hepatic adenoma and cholangiocarcinoma, and three cases of hepatocellular carcinoma, two with widespread metastases, are reported.

9.6.11 Exocrine Pancreatic Conditions

There are few reports of exocrine pancreatic disease in African pygmy hedgehogs. A single case each of pancreatitis and pancreatic carcinoma exist.

9.7 Cardiovascular Conditions

The anatomy of the heart of *Atelerix albiventris* has not been specifically described, but in the European hedgehog the heart valves are mainly muscular, the inter-atrial septum is composed of a very thin layer of fibrous tissue, and there is cartilage in the heart base. Incidental foci of myocardial mineralization are seen sporadically. Cardiac insufficiency as a result of myocardial mineralization is commonly seen in association with chronic renal failure in African pygmy hedgehogs.

9.7.1 Cardiac Insufficiency

Congestive heart failure due to endocardiosis of the mitral valves has been reported in an adult African pygmy hedgehog. The animal had a 2-week history of lethargy, reduced appetite, and weakness. Severe cardiomegaly, left atrial and ventricular dilation, and nodular thickening of the mitral valve leaflets were noted on gross examination. Microscopic changes in the valves included hyalinization and fragmentation, and increased fibroblasts and basophilic myxoid matrix. Concurrent vacuolation of the white matter in the brain and spinal cord, consistent with wobbly hedgehog syndrome, may have contributed to the animal's clinical signs.

9.7.2 Cardiomyopathy

Cardiomyopathy is moderately common in aging hedgehogs and animals may die without premonitory signs.

Figure 9.4 Ascites in a hedgehog with underlying heart disease. *Source:* Courtesy of C. Wheler.

On gross examination, cardiomegaly, hepatomegaly with rounded nutmeg livers, pulmonary congestion and edema, and ascites may be seen (Figure 9.4). Microscopically, myocardial degeneration with myonecrosis and mineralization are noted. Acute renal tubular necrosis resulting from poor renal perfusion is also common. No specific cause for cardiomyopathy has been determined, although genetic and nutritional factors may underlie some cases.

9.7.3 Myocarditis

Myocarditis has been reported in several cases, two from Texas, subsequent to *Trypanosoma cruzi* infection. A mild zoonotic risk is present as blood from infected animals may be infectious to humans. In both animals, infection was proposed to result from ingestion of infected *Triatoma* sp. insects.

9.7.4 Other Cardiovascular Conditions

Severe, bilateral cardiac mural thrombosis was diagnosed in a 4 year-old African pygmy hedgehog with clinical signs of depression, weakness, and bilateral hind leg paralysis. Gross post-mortem examination revealed an animal in good body condition, with a markedly enlarged, globular heart caused by bilateral atrial thrombosis. Although a specific cause for the hind leg paralysis was not found, it may have been due to emboli lodging in the hind limb vessels.

Myocardial necrosis and mineralization were described in a 1 year-old female African pygmy hedgehog, with a 1-week history of decreased appetite and lack or energy, culminating in death. Microscopic examination of the heart showed multifocal necrosis and severe mineralization of the left ventricle. Both kidneys exhibited focal depressed areas on their surfaces which correlated with wedge-shaped areas of necrosis and fibrosis of the cortex. Although the etiology of the myocardial necrosis was not discovered, selenium or vitamin E deficiency was suggested as a cause. Renal lesions were thought to be due to hypoxia from impaired cardiac function.

A hemangioma in the apex of the left ventricular free wall has been described as an incidental finding in 3.5 year-old female African pygmy hedgehog.

9.8 Genitourinary Conditions

African pygmy hedgehogs breed throughout the year in captivity. Sexual maturity can be reached as early as 2–3 months of age for females, and 5–8 months of age for males. Castration and ovariohysterectomy can be performed, but are not done routinely.

In the male, the prepuce and penis are located on the ventral mid-abdomen. There is no scrotum, the inguinal rings are open, and the testes are located in subcutaneous para-anal recesses and may or not be palpable. The testes and vas deferens are normally surrounded by fat. The penis is spineless with lateral horns on either side of the meatus.

In the female, the opening of the urogenital tract is only a few mm ventral (cranial) to the anus. The vagina is long and always open, and the bicornuate uterus begins immediately at the single muscular cervix; there is no common uterine body. A fan-shaped gland homologous to Cowper's gland lies on either side of the vagina. The short (7.5 mm) and simple Fallopian tubes emerge terminally from the side of each uterine horn and extend back along the horn. There are no sperm storage glands, as are present in some other insectivores. The mesosalpinx and ovarian bursa generally contain large amounts of fat. The ovaries are held within a tough peritoneal capsule. The placenta is discoid, lies on the antimesometrial side of the uterus and is hemochorial.

9.8.1 Urinary Tract Conditions

Renal disease is common in African pygmy hedgehogs, with a prevalence of up to 50%. Clinical signs include polyuria and polydypsia, lethargy, and weight loss. On gross examination, affected kidneys are often small and have a

Figure 9.5 Penile prolapse in an African pygmy hedgehog. *Source:* Courtesy of C. Wheler.

roughened, pitted appearance with an adherent capsule. Pale wedge-shaped lesions, linear streaks and foci, and a granular appearance may be seen in the cortex on gross examination of cut sections. Polycystic kidney disease occurs sporadically. A wide range of pathologic processes are seen including tubulointerstitial nephritis with a lymphoplasmacytic interstitial infiltrate, linear cortical interstitial fibrosis; nephrosis, tubular necrosis, and tubular regeneration; membranoproliferative glomerulonephritis or glomerulopathy with tubular dilation and hyaline renal casts, and glomerular sclerosis; subacute to chronic renal cortical infarction; nephrocalcinosis; and focal osseous metaplasia. There is no general consensus on the reasons for the development of renal disease.

Cystitis, crystalluria, and urolithiasis, and renal nephroliths, including bilateral staghorn calculi in the renal pelvis, may occur. It has been suggested that these processes may be linked to cat food diets. Urethral obstruction can occur in the male, and penile prolapse is seen sporadically (Figure 9.5). Reported renal neoplasms include transitional cell carcinomas of the bladder, adenocarcinomas, hemangioma, and hemangiosarcoma.

9.8.2 Reproductive Tract Conditions

Abortion, stillbirth, uterine rupture and dystocia can occur in African pygmy hedgehogs, but dystocia is rare.

Young hedgehogs can be aged to some degree by development: as a rough guideline for African pygmy hedgehogs, spines erupt within 24 hours after birth, ears open at 14–18 days of age, eyes remain closed until 15–24 days of age. The hair on the ventrum and face develops by 3 weeks of age, deciduous teeth erupt at 3–4 weeks of age, and permanent dentition emerges at 7–9 weeks of age. Weaning generally takes place 4–6 weeks after birth and full adult size is reached at approximately 2–3 months of age.

Few conditions of the male reproductive system have been described. These include posthitis associated with substrate trapped in the prepuce and paraphimosis associated with a swollen penis. Neoplastic conditions include one Sertoli cell tumor in an undescended testicle. A periurogenital neurofibrosarcoma was seen in one male African pygmy hedgehog.

9.8.2.1 Neonatal Mortality

Maternal desertion and cannibalism of the young by either parent can occur, especially with animals that are not well socialized. Failure of lactation is considered a common cause of unexplained neonatal deaths. Based on data from European hedgehogs, the main colostral transfer of maternal antibodies is thought to take place over the first 24–72 hours after birth; however, transmission of maternal immunoglobulins appears to continue through the suckling period. Lack of colostrum has been associated with increased susceptibility to infectious disease. Bacterial infections can lead to bacteremia, septicemia, and death.

9.8.2.2 Uterine Conditions

Causes of uterine discharge include pyometra and metritis, endometrial polyps, endometrial venous aneurysms, diffuse endometrial hyperplasia with cysts, uterine stromal hyperplasia, and neoplasia (Figure 9.6). The discharge is frequently bloody and can be confused with hematuria.

Uterine disease, both neoplastic and non-neoplastic, is common in the African pygmy hedgehog with multiple pathological processes frequently present in the same uterus.

One case series described proliferative lesions in the uteri of 15 African pygmy hedgehogs, all of which presented with vaginal bleeding or hematuria. All uteri had numerous small and ill-defined areas of stromal cell hyperplasia restricted to the superficial endometrium with no cellular atypia or increased mitoses. These findings suggest that ovariohysterectomy may prolong survival of hedgehogs with uterine tumors.

Other reported uterine lesions include adenomatosis, endometrial polyps, uterine adenocarcinoma, cervicouterine squamous cell carcinoma, stromal cell sarcoma, leiomyoma, and leiomyosarcoma. In most cases, the uterus is grossly distorted by the presence of the neoplasm and there is often a history of vaginal bleeding.

9.8.2.3 Ovarian Conditions

Ovarian disease is seen much less frequently. Granulosa cell tumors have been reported twice with microscopic characteristics as seen in other mammals. One case of a malignant ovarian teratoma has been described in a 1.4 year-old African pygmy hedgehog. The mass incorporated both ovaries and a portion of one uterine horn. On microscopic

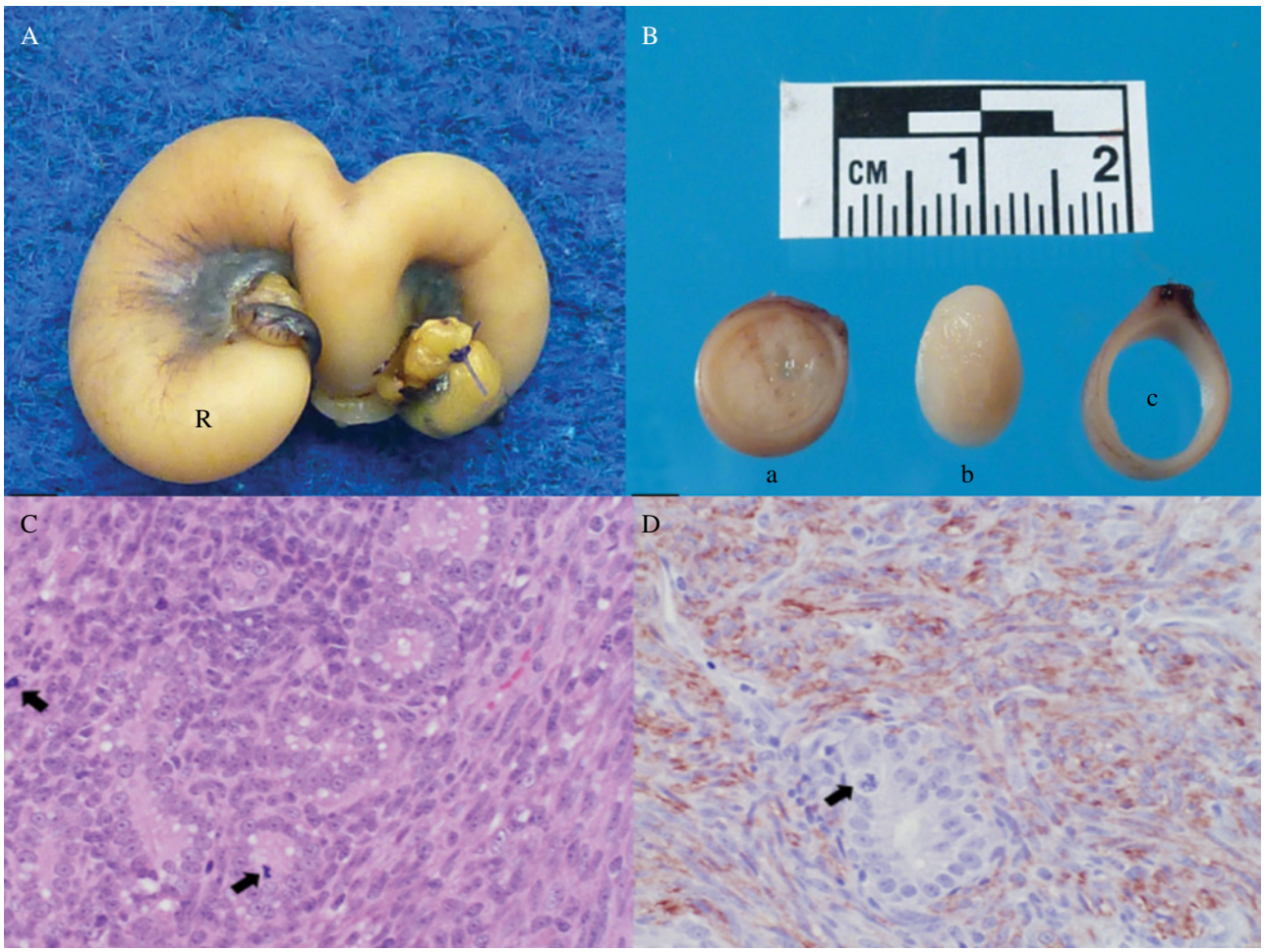

Figure 9.6 A: Formalin fixed uterus, removed surgically. Right horn (R) is larger than the left due to the presence of a hyperplastic endometrial polyp. B: Right horn transversely sectioned at the point of attachment of the polyp (a), the rounded free end of a section of polyp (b) that was freely moveable in the distended lumen of the adjacent uterus (c). C: Photomicrograph of uterine stromal tumor. Glandular epithelial profiles are embedded in solid sheets of fusiform, streaming endometrial stromal cells. Mitotic figures are present (arrows). D: Widespread positive immunolabeling of stromal cells for alpha smooth-muscle actin.

evaluation, tissues of all three germ layers and embryonic (immature) cells were noted and neoplastic cells were also present in lymphatics and a peritoneal metastasis.

9.9 Nervous System Conditions

The olfactory lobe and vomeronasal organ of the hedgehog are well developed, reflecting the importance of the sense of smell.

Differential diagnoses for clinical signs suggesting nervous system involvement include trauma, intervertebral disc disease and spinal cord compression, vertebral osteosarcoma, wobbly hedgehog syndrome, otitis media, infection, hepatic encephalopathy secondary to hepatic lipidosis, and neoplasia. Hedgehogs are also susceptible to neurologic disease caused by migration of *Baylisascaris* species and to polioencephalomalacia; a nutritional deficiency causing degeneration of the white matter of the brain. Hypocalcemia, responsive to calcium supplementation, has been reported anecdotally in association with postpartum eclampsia, malnutrition, and as an idiopathic condition. Animals in torpor must be differentiated from those with true neurological disease. Lumbar polyradiculopathy, characterized by ballooning myelin sheaths and axonal distortion in the dorsal and ventral intradural nerve rootlets, was described as an age-related change in a 1 year-old hedgehog of undescribed species.

9.9.1 Intervertebral Disc Disease and Spinal Compression

Clinical signs of intervertebral disk disease include progressive hind limb ataxia, proprioceptive loss, lameness, and urinary stasis. Cases involving the cervical

and lumbar vertebrae are reported and survey radiographs may demonstrate spondylosis and narrowing of the cervical intervertebral spaces. Microscopically, intervertebral discs show features of chondrodystrophic breed-associated disc disease in canids, including degeneration and mineralization of the nucleus pulposus and annulus fibrosis, and dorsal protrusion into the vertebral canal. Bridging osteophytes may be seen. In one case, a fibrocartilaginous embolus was present within a longitudinal venous sinus.

9.9.2 Wobbly Hedgehog Syndrome

This condition may affect up to 10% of African pygmy hedgehogs in North America. The cause is unknown, but there is no evidence for transmission of the condition, no gender bias, and reported cases are restricted to certain family lineages. Hence, an inherited condition is suspected. Initial clinical signs include an inability to pull the quills (the 'hood') over the face, and mild ataxia and incoordination, particularly related to hindlimb function. Progressive paralysis ensues with the hedgehogs eventually being unable to even lift their heads. Although animals remain alert, problems develop with dysphagia and an inability to prehend and masticate food. Other clinical signs include tremors, seizures, falling consistently to one side, exophthalmos, self-mutilation, and problems regulating body temperature. Clinical signs may wax and wane and the onset generally occurs in animals less than 2 years of age, with most animals developing complete paralysis within 9–15 months. No treatment has been effective in slowing the disease progression. Diagnosis is based on histopathology; gross lesions reflect secondary changes such as emaciation, neurogenic muscle atrophy, secondary scoliosis, and fatty liver. The hallmark lesions include vacuolation of the white matter of the cerebrum, cerebellum, brainstem, and spinal cord; the condition is not inflammatory (Figure 9.7). Myelin loss is followed by axonal and then neuronal degeneration. Gliosis and the presence of gemistocytic astrocytes develop with time. Lower motor neurons in the spinal cord may also be affected, but dorsal rootlets, spinal and peripheral ganglia, and peripheral nerves are not.

9.9.3 Other Encephalitides

Rabies has been diagnosed in wild European hedgehogs. There is little reason to suspect that African pygmy hedgehogs would not also be susceptible.

Severe meningoencephalitis was diagnosed in an orphaned young European hedgehog. Eosinophilic intranuclear inclusion bodies were present in the neurons and the glial cells, and immunohistochemical labeling was positive for herpes simplex virus 1 and 2 antigens. The animal was assumed to have acquired the infection from a human carrier.

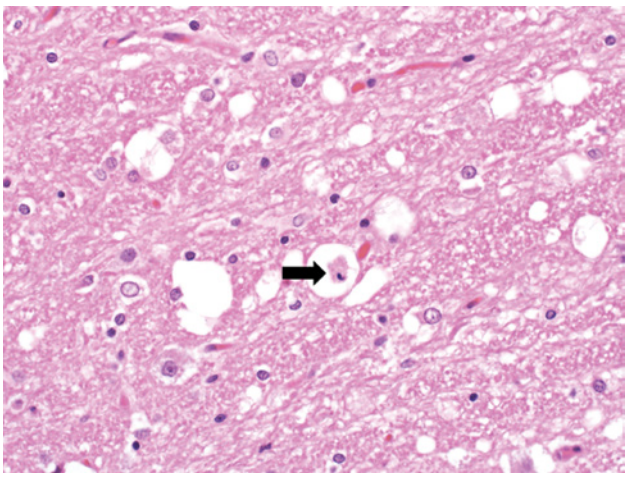

Figure 9.7 Vacuolation of white matter tracts in the brainstem of a hedgehog with wobbly hedgehog syndrome. A gitter cell is present (arrow).

Chronic diffuse lymphoplasmacytic meningoencephalitis was described in a 1 year-old male African pygmy hedgehog with clinical neurologic signs. No etiologic diagnosis was made. The animal had a concurrent mild suppurative otitis interna.

Nonsuppurative encephalitis was described in an approximately 6 month-old African pygmy hedgehog in Japan with clinical signs consistent with wobbly hedgehog syndrome. Microscopic lesions consisted of a nonsuppurative encephalitis, with lymphohistiocytic meningitis, perivascular cuffs, lymphocytic infiltration of the neuropil, reactive microgliosis and scattered neuronal degeneration and necrosis. The cerebrum, cerebellum, thalamus, and brainstem were all affected. Vacuolation associated with demyelination and Wallerian degeneration were particularly prominent in the cerebellum. There was also a mild cardiomyopathy. RNA reads from the brain were highly homologous (96.5% on whole genome sequencing) with pneumonia virus of mice (PVM) strain 15, a paramyxovirus; PVM antigen was also identified by IHC in brain and lung.

9.9.4 Neoplasia of the Nervous System

Neoplasia of the central nervous system is more common in the African pygmy hedgehog than in other mammalian species. Tumors reported include astrocytoma, microglioma, and fibroblastic meningioma, and no metastases were identified. Ganglioneuromas also occur sporadically.

Two cases of anaplastic astrocytoma have been described in African pygmy hedgehogs that were approximately 2 years old; both animals showed clinical signs of

progressive hind limb to forelimb paresis. The first case involved a tumor in the spinal cord and immunohistochemical labeling of neoplastic cells was strongly positive with GFAP and S-100. In the second case, the tumor occurred in the medulla oblongata and spinal cord and GFAP labeling was strongly positive in some tumor cells. In both cases, the clinical picture could be confused with that of wobbly hedgehog syndrome.

A single case of an oligoastrocytoma was identified in a 3.5 year-old female African pygmy hedgehog with a 6-month clinical history of circling, progressing to falling to one side. At necropsy, neoplastic cells had infiltrated large portions of the cerebrum, cerebellum, and brain stem. Morphologic features reflected two distinct populations of neoplastic cells, which was further supported by immunohistochemical testing. One cell population was positive for GFAP and vimentin, while the other was positive for isoform A of the neuritic outgrowth inhibitor (Nogo-A) and oligodendrocyte transcription factor Olig-2, indicating the presence of a mixed astrocytic and oligodendroglial neoplasm.

9.10 Hematopoietic and Lymphoid Conditions

Hematologic and biochemical reference intervals for the African pygmy hedgehog have been published. General interpretation of parameters is no different than for other mammalian species.

Splenic extramedullary hematopoiesis and associated splenic enlargement are very common in both male and female African pygmy hedgehogs. Affected spleens are diffusely red brown and over 50% of the splenic parenchyma can be diffusely or multifocally replaced by a combination of erythroid, myeloid, and platelet lineages. This condition is likely a nonspecific finding, rather than a reflection of clinical disease and increased demand.

9.10.1 Hereditary Congenital Erythropoietic Porphyria

Hereditary congenital erythropoietic porphyria was described in a 6 month-old African pygmy hedgehog. The animal had pink teeth, and urine, which fluoresced under ultraviolet light. Spectrophotometric and thin layer chromatography of urine and feces from the affected animal, its dam, and control animals were used to make the diagnosis.

9.10.2 Histoplasmosis

A single case of histoplasmosis has been described in a 2 year-old African pygmy hedgehog living indoors in an area endemic for the disease. Clinical signs over an approximately 6-week clinical course included inappetence, lethargy, weight loss, and splenomegaly. The animal was anemic with decreased white blood cells and platelets. It died and at post-mortem examination, there was severe splenomegaly, with the spleen weighing 2.4% of body weight, and mild hepatomegaly. Granulomatous inflammation with multinucleated giant cells was present in multiple organs including the spleen, the liver, the kidney, the myocardium, the lung, and the gastric and enteric lamina propriae. Intralesional yeasts were diagnosed as *Histoplasma capsulatum* var *capsulatum* based on morphology. The source of infection was assumed to be dust in the air or bedding.

9.10.3 Lymphosarcoma

Lymphosarcoma is commonly seen in African pygmy hedgehogs and affected animals are typically over 3 years of age. The tumor can occur in any tissue and it is generally multicentric in distribution, although a number of gastrointestinal cases have been reported with metastasis to mesenteric lymph nodes.

Only one report describes hematologic findings in conjunction with histopathology. A 4 year-old male African pygmy hedgehog with a history of decreased appetite, weight loss, and intermittent tarry stool had a marked lymphocytosis (48 x 10^9/L) with abnormal lymphocytes in circulation. At necropsy, lymphosarcoma was diagnosed with neoplastic cells in the stomach, intestines, the pancreas, and the regional lymph nodes. The bone marrow was unaffected.

9.10.4 Myelogenous Leukemia

Multiple cases of myelogenous leukemia have been reported in African pygmy hedgehogs. A complete blood count may demonstrate marked leukocytosis (100 x 10^9/L) and neutrophilia (84 x 10^9/L) with a profound left shift, including cells as early as myelocytes. A substantial number of circulating undifferentiated blast cells may be seen in addition to anemia. Numerous mature and immature granulocytes with eosinophilic granules and round to ovoid, sometimes indented and hyperchromatic, nuclei are seen in the blood vessels and the heart as well as the spleen, lymph nodes, renal glomeruli, the bone marrow, and the liver.

9.10.5 Other Hematopoietic Neoplasms

Splenic hemangiosarcoma is seen sporadically in hedgehogs. A plasmacytoma was identified in the large intestine of a 3 year-old male African pygmy hedgehog. The animal had a brief history of anorexia and weight loss

Figure 9.8 Ocular trauma in a hedgehog. *Source:* Courtesy of C. Wheler.

before death. Neoplastic round cells with plasmacytoid features diffusely infiltrated the lamina propria and submucosa, with extension to the muscularis and mesocolon with few mitotic figures and occasional multinucleated giant cells. Diagnosis was based on the light and electron microscopic examination of the neoplastic cells.

9.11 Ophthalmic Conditions

Animals have been trained to discriminate between certain colors, particularly in good light. A retro-orbital sinus is present in the African pygmy hedgehog.

African pygmy hedgehogs have a wide palpebral fissure and a shallow orbit which can predispose to proptosis or injury, particularly in animals with large amounts of retrobulbar fat, periocular inflammation, or other causes of peri- or retro-orbital swelling (Figure 9.8). Lesions may be far advanced before they are identified due the small eye size and the shy nature of some individuals. Reported ocular lesions include corneal ulceration and perforation, hyphema and vitreous hemorrhage, and panophthalmitis. Cataracts occur sporadically and Meibomian cysts have been described.

Intraocular hemangioma, acinic cell carcinoma, and lacrimal gland carcinoma have all been described as single case reports in African pygmy hedgehogs.

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28

Surgery

Zdeněk Knotek and Stacey Leonatti Wilkinson

Introduction

In reptiles, standard surgical methods apply, although the unique anatomy of reptiles and the huge variety in patient size are important factors to consider.

Patient Assessment and Preparation for Surgery

Preoperative physical examination is vital. Pre-anaesthesia blood work, such as a complete blood count and chemistry panel, are ideal. Diagnostic radiography, ultrasound, computed tomography (CT) and magnetic resonance imaging (MRI) are useful in both presurgical patient assessment and surgical planning. Reptile patients generally do not require fasting for surgery, as they are not prone to regurgitation under anaesthesia, nonetheless, fasting (lizards 1–2 days, snakes 2–3 days, tortoises 3–5 days) is recommended for elective surgery on the gastrointestinal tract.

Pre- and Perioperative Care

Many surgical procedures are not true emergencies and the patient may need to be hospitalized for supportive care measures prior to surgery. Thermal support is provided to the reptile patient before, during and after surgery. Before surgery, the patient is given analgesia (e.g. a combination of opioids and nonsteroidal anti-inflammatory drugs, NSAIDs) and fluids (see Chapter 27 and Appendix 1). After 30–45 minutes, anaesthetic drugs are given and the patient is prepared for intubation. After successful intubation, the patient is placed under inhalation anaesthesia using isoflurane or sevoflurane and oxygen.

Positioning

Most lizards and crocodilians are positioned similarly to mammals (e.g. ventral, lateral or dorsal recumbency). Chameleons are best positioned in lateral recumbency. For surgery involving the coelomic cavity, snakes are best positioned in right lateral recumbency (left lateral approach) to avoid the incision of the right air sac. Turtles and tortoises, when placed in dorsal recumbency, can be placed in the middle of a towel rolled into a ring.

Patient Preparation

Plastic adhesive drapes are recommended to aid visibility of the surgical field. Alternatively, spray adhesives may be used on standard

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drapes. Standard patient surgical preparation is undertaken. When shell repair is necessary for chelonian patients, the surface of the shell must be prepared by cleansing and degreasing the surface, to enable restorative material to adhere to the shell.

Instruments

Small reptile patients necessitate the use of fine ophthalmological surgical instruments (e.g. micro haemostats, iris scissors), while large chelonians or crocodilians may require special equipment; for example for orthopaedic surgery. Haemostatic clips are useful where application of ligatures is difficult. Absorbable gelatin sponges should be used for controlling haemorrhage in reptiles (Figure 28.1). Eyelid retractors work well as wound retractors. Lone Star Veterinary Retractor Rings (type 4407G or 4405G, with retractor hooks, Cooper Surgical) are ideal for middle-sized and large reptile patients.

Sutures, Radiosurgery and Surgical Laser

Most reptiles do not traumatize surgical incisions. This makes closure with a continuous pattern safe and efficient (Mader *et al.* 2006). In the reptile, synthetic absorbable suture materials are absorbed very slowly. Recommended suture materials for the reptile patient are monofilament thread (e.g. Caprolon®, a copolymer of lactic acid and caprolactone), nylon or polypropylene (Mader *et al.* 2006). Wound healing is slow in reptiles and suture removal is generally scheduled four to six weeks after surgery. Skin closure is best accomplished with an everting suture pattern such as horizontal or vertical mattress. Radiosurgery is useful in reptile patients for skin incision, body wall incision, organ biopsies and a variety of other procedures. Bipolar forceps allow fine coagulation of vessels. Surgical lasers are used for precise cutting through reptile skin to minimize blood loss (Hodshon *et al.* 2013).

Soft-Tissue Surgery

Skin Wounds and Burns

Many wounds will heal by second intention with appropriate topical wound care and antibiotic use. However, some are large enough that repair is needed. Large wounds will eventually granulate and heal but may take months of care for full healing. Wounds on the chelonian shell can take up to one year or more to fully heal (Mader *et al.* 2006, Alworth *et al.* 2011).

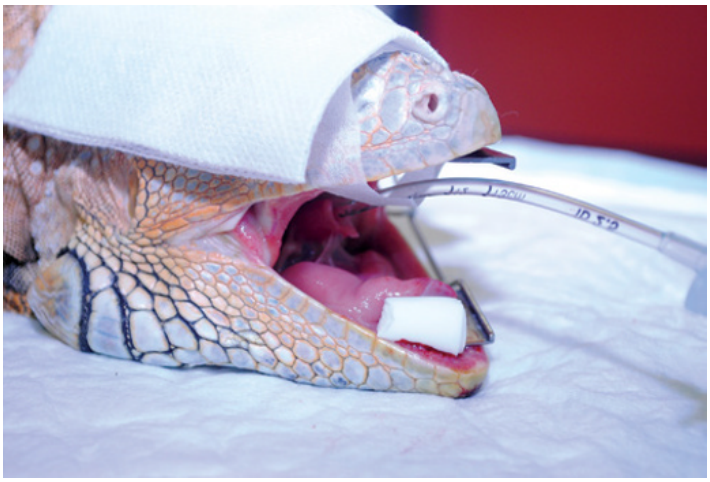


Figure 28.1 Absorbable gelatin sponges are useful for controlling haemorrhage in reptiles.

Subcutaneous Abscess Removal

There are different options for surgical management of abscesses in reptiles (Figure 28.2). One option is to lance the abscess, remove the caseous material inside and leave the wound open to heal by second intention (Mader *et al.* 2006, Alworth *et al.* 2011, Huchzermeyer and Cooper 2000). The cavity is then flushed daily with dilute chlorhexidine or povidone iodine and antibacterial creams or ointments are used to pack the capsule. Poloxamer gel infused with antibiotics may also be used. Another option is to remove both the inner caseous material and the entire fibrous capsule as well (Mader *et al.* 2006, Alworth *et al.* 2011). The resulting wound can be left open (to heal by second intention and should be cleaned daily and topical antibacterial creams applied if needed) or sutured closed.

Aural Abscesses

Aural abscesses are common in chelonians, specifically aquatic turtles and box turtles. The swelling over the ear is lanced and the caseous material removed. The skin over the ventral half of the ear is removed to keep the cavity open and allow it to heal (Murray 2006). The cavity is flushed with saline, appropriate antibiotic therapy is prescribed and any husbandry deficiencies corrected.

Subspectacular Abscess

Subspectacular abscess typically develops from bacteria that ascend the nasolacrimal duct from the mouth and colonize the subspectacular space but it can also arise from a penetrating wound to the eye or haematogenous spread (Alworth *et al.* 2011). An incision is made in the ventral half of the spectacle and a 30–90-degree wedge of the spectacle is removed (Alworth *et al.* 2011, Lawton 2006). A sterile swab in inserted to remove material for cytology and culture, then a small catheter (such as an intravenous catheter) is inserted and the area flushed with saline. Antibiotics can be flushed inside the spectacle and systemic antibiotics are often indicated, ideally chosen based on culture and sensitivity results (Lawton 2006). Within 24 hours, a hyaline proteinaceous plug and inflammatory debris fills the defect, sealing the subspectacular space and providing a barrier while healing progresses. This plug may need to be gently disrupted daily to apply topical antibiotics to the subspectacular space. By 21 days, healing has typically progressed such that the snake will have a multilayered regenerating spectacle and will have re-established subspectacular space. By three months, the spectacle is usually fully healed.

Figure 28.2 Surgical curettage of a mandibular abscess in a green iguana (*Iguana iguana*).

Nasolacrimal Duct Obstruction and Pseudobuphthalmos

Blockage of the nasolacrimal duct is most commonly encountered in snakes and geckoes (Alworth *et al*. 2011, Lawton 2006). As with an abscess, a wedge in the ventral aspect of the spectacle can be removed to allow the fluid to drain. Fluid should be collected from the subspectacular space and cytology performed to rule out other causes of fluid accumulation, as flagellates have been reported (Lawton 2006). If the problem recurs, a conjunctivoralostomy can be performed by inserting an 18-guage needle at the medial aspect of the inferior fornix of the subspectacular space and emerging on the roof of the mouth between the palatine and maxillary teeth. A fine silicon tube is threaded through the needle, the needle removed and the tube sutured in place on the periorbital scales and left in place for at least six weeks (Alworth *et al*. 2011, Lawton 2006, Millichamp *et al*. 1986).

Enucleation

In species with eyelids, the globe and all ocular tissue are removed and the eyelid margins are removed and sutured together (Alworth *et al*. 2011). In snakes or lizards with a spectacle, a circular incision is made around the entire circumference of the spectacle and all ocular tissue is removed. Vessels can be ligated with small suture, vascular clips or radiosurgery, or a gelatin sponge or direct pressure can be applied for haemostasis. The wound is left open to heal by second intention (Alworth *et al*. 2011, Lawton 2006).

Eyelid Surgery

There are many species in which one eyelid is more moveable than the others (the lower lid in lizards and chelonians and the upper lid in crocodilians). This needs to be accounted for when performing surgery and considering the function of the eyelids postoperatively (Lawton 2006). Snakes do not have eyelids.

Tracheal Resection and Anastomosis

Chondromas arising from the tracheal cartilage have been reported in snakes and can grow large enough to obstruct the airway and cause significant dyspnoea. Resection and anastomosis of the trachea is the treatment of choice. The anaesthetized patient is intubated with a long polypropylene or rubber catheter to the level of the mass. Stay sutures using a fine monofilament suture are placed and the affected area of the trachea removed. The catheter is advanced into the distal part of the trachea, both to help to realign the trachea for closure and to maintain anaesthesia. The absorbable sutures should encompass at least one or two tracheal rings on each side of the incision. All sutures are preplaced and then tightened. Care should be taken not to damage the dorsal tracheal membrane during the procedure. The trachea is tested for leaks by dribbling saline on the incision and watching for bubbles (Mader *et al*. 2006).

Surgery of the Tongue

In chameleons, small wounds of the tongue can be managed by putting the tongue back in its sheath and suturing. Serious or prolonged tongue injuries may involve complete or partial amputation of the tongue. The veins and tongue are carefully ligated rostrally, just before the attachment to hyoid apparatus, and the damaged part is snipped off. The cartilaginous apex of the hyoid bone should be adequately shortened to reduce the risk of perforation of the tongue stump. The patient may require hand feeding long term, although snakes have managed to eat normally after tongue amputation (Brendan Carmel, personal communication).

Oesophagostomy Tube Placement

Placement of an oesophagostomy tube is most commonly indicated in chelonians and can be placed in a similar manner in

lizards. A tube should be premeasured and marked so that it can be inserted the distance from the cranial rim of the plastron to the junction of the pectoral and abdominal scutes. A curved pair of hemostats is inserted into the oral cavity. The hemostats are pushed laterally in order to 'tent' the skin on either side of the neck and allow the vessels on the neck to 'roll' out of the way so as not to be damaged. An incision is made on the lateral aspect of the neck where it meets the shoulder, just large enough to pass the tips of the hemostats out of the incision. The distal end of the feeding tube is grasped and pulled through the incision and back out of the mouth; it is then redirected and passed down the oesophagus into the distal oesophagus or proximal stomach. The tube is secured in place at the skin with a purse-string suture and, ideally, a Chinese finger-trap suture is placed around the tube with nonabsorbable material. Finally, the tube is taped or sutured in place along the animal's dorsum. Radiographs or endoscopy can be used to confirm proper placement. When removal is necessary, the sutures and tube can be removed and the surgical site left to heal by second intention (Alworth *et al*. 2011).

Coeliotomy

Coeliotomy has a wide range of applications (Mader *et al*. 2006, Alworth *et al*. 2011; Figure 28.3). Indications include reproductive disorders, gastrointestinal disease, urinary system dysfunction and exploration for obtaining organ biopsies. In all species, a nonabsorbable suture material is used for closing the skin in a continuous everting pattern. Sealing the incision site with tissue glue may help prevent postoperative infection. Plastron or carapace fixation should remain for approximately six months before removal. For at least 10–14 days postoperatively, the patient should remain in a warm and dry environment. Antibiotics and fluid therapy may be required. If the patient is anorectic, forced feeding may be required.

Coeliotomy in Lizards

Most lizards are positioned in dorsal recumbency, except chameleons, which are placed in the lateral recumbency, with the head and hind legs fixed to the drape. The skin is incised along the curvature of the ribs (chameleons) or in paramedial line of the abdominal wall (other lizards). Lone Star Veterinary

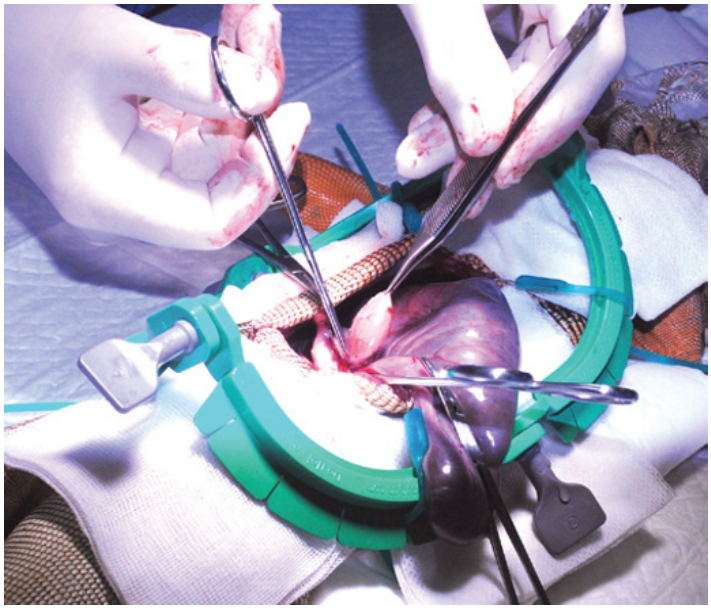


Figure 28.3 Coeliotomy in a green iguana (*Iguana iguana*).

Retractor System may be used for improved access to the surgical field and better visibility of organs. The skin is separated from the muscle layer. The muscle layer and pleuroperitoneum are incised along the curvature of the ribs (in chameleons) or in the paramedial line (other lizards). In chameleons, the surgeon must be careful not to damage small veins located around the ribs. In chameleons, pause IPPV before entering the body cavity; if this is not done, air sacs may sharply protrude into the surgical incision. In other lizards, entering the body cavity is much easier. Take care to avoid the ventral abdominal vein by performing a paramedial incision or by starting caudally and incising the skin cranially on the midline. The muscle layer and pleuroperitoneum are closed (together in small patients and as two separate layers in large lizards) with 3-0 4-0 guage absorbable sutures in a simple interrupted pattern. Thereafter, 3-0 or 4-0 absorbable material or 3-0 non-absorbable material is used for closing the skin, as previously described.

Coeliotomy in Snakes

The snake is positioned in right lateral recumbency and fixed to a sterile drape. The incision is made between the first and second row of lateral skin scales. The muscle layer and the pleuroperitoneum are gently perforated. At the end of the surgical procedure, the pleuroperitoneum and the muscle layer are closed (together in small patients and as two separate layers in large snakes) with a single simple continuous pattern of absorbable material.

Coeliotomy in Chelonians

In chelonians, a plastronotomy is needed to reach the organs in the coelom (Figure 28.4a,b,c), except in sea turtles, where the oesophagus and stomach can often be accessed through an axillary incision. Oscillating saws or small circular saws are ideally suited for cutting through shell. The blades must not be overused, as a dull blade does not cut well and prevents proper healing. With careful handling, the same blade can be used for two to three patients before requiring disposal.

Ovariectomy

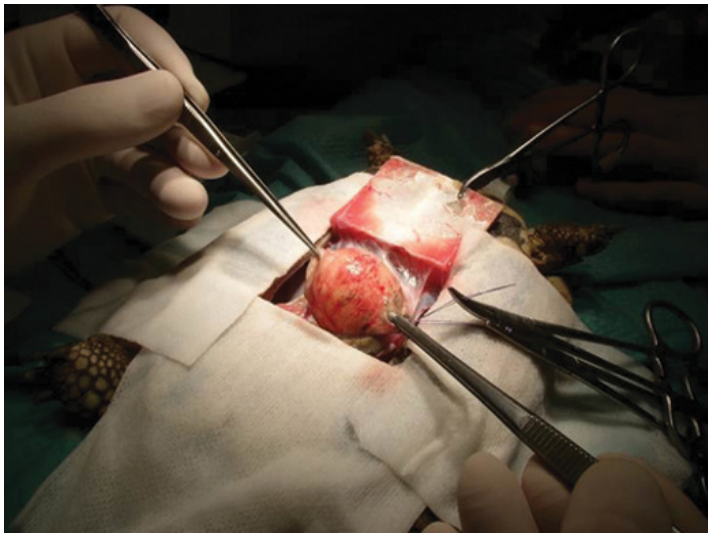
Ovariectomy is a common surgical procedure in lizards and chelonians. Once the coelom is entered, the fat body and the ipsilateral ovarium with follicles are exteriorized. In chelonians, this can be done through a pre-femoral incision or plastronotomy. An avascular area of ovarian interfollicular connective tissue is selected for placement of finger or grasping forceps, taking care to avoid rupture of ovarian follicles. Gentle traction is applied and the ovary is cautiously retracted toward the coelom incision. The ovarian vasculature is ligated with suture or haemostatic clips and the mesovarium is transected. Care must be taken not to accidentally remove the adrenal gland. The ligation sites are examined to verify haemostasis and to confirm complete excision of all ovarian tissue. The second ovary is exteriorized and resected in the same way as the first. The surgeon should ensure that all follicles are removed. If very small follicles (smaller than a pinhead) are overlooked, they can dramatically enlarge within few weeks or months and the surgery needs to be repeated. If the ovaries are being removed for prophylactic reasons and the oviducts are healthy, the latter can be left in place.

Salpingectomy

Salpingectomy is usually indicated in cases of postovulatory egg stasis in lizards and chelonians, removing the entire oviduct, eggs included. The distal part of the oviduct and veins in the mesosalpinx are ligated with sutures (Figure 28.5) or haemostatic clips and the mesosalpinx is transected close to the cloaca and removed.

(a)

(b)



(c)

Figure 28.4 (a) Tortoise positioned in dorsal recumbency for plastronotomy. (b) A square segment of plastron is gently elevated to provide excellent exposure for a cystotomy. (c) A sound seal over the surgical wound is essential for good healing after a plastronotomy.

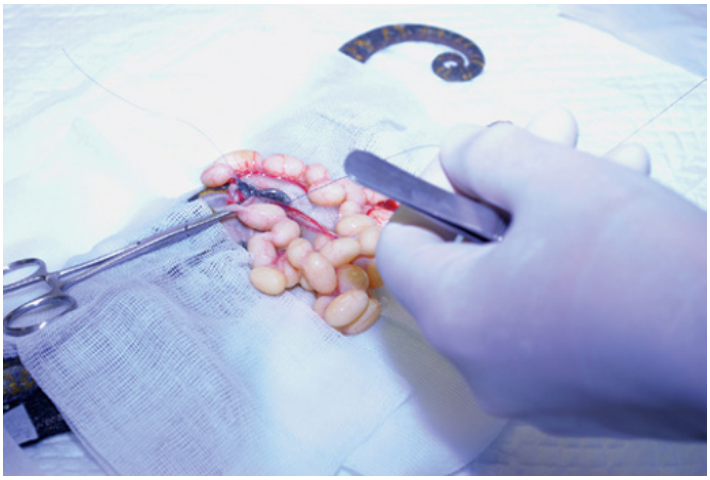


Figure 28.5 Ligation of the ovarian vasculature in a chameleon.

Salpingotomy

Salpingotomy is the same regardless of species. Surgical intervention is usually required for causes of dystocia in snakes (Alworth *et al*. 2011). The oviduct is gently elevated out of the coelom and assessed. Two absorbable fixation sutures are made in the wall of the oviduct and the central part of the oviduct wall is incised. An incision is made over the eggs. To decrease the distance between the eggs, they are gently massaged closer to the incision from the proximal and distal parts of the oviduct. Eggs are gently withdrawn from the lumen of the oviduct and the mucosa washed with warm sterile saline. The wall of the oviduct is sutured with a single simple continuous pattern of absorbable material and the pleuroperitoneal cavity is then evaluated and examined for any local complications (Mader *et al*. 2006, Alworth *et al*. 2011).

Orchidectomy in Lizards

The surgical technique is similar to that described for ovariectomy. The gonads are tightly adhered to adjacent structures, so excellent exposure is vital for successful removal. The right testicle is attached to the vena cava by very short vessels while the left adrenal gland sits between the testicle and its blood supply. Avoid removing or damaging this gland during surgery, although a patient can survive if it is inadvertently removed. The testes are gently elevated to expose the vasculature; a fine suture can be placed in the capsule to aid this if needed. The vessels ligated with haemostatic clips and the testicle removed. It is vital that all areas are ligated properly before cutting, as marked haemorrhage can occur. It is also important to ensure all testicular tissue is removed, as it can regrow if cells are left behind (Mader *et al*. 2006, Alworth *et al*. 2011).

Gastrotomy and Gastrectomy

In lizards and chelonians, the stomach is anchored tightly, making it difficult to fully exteriorize; however, it is much more mobile in snakes. In chelonians, a plastronotomy is needed to reach the stomach, except in sea turtles, where the oesophagus and stomach can often be accessed through an axillary incision. The stomach is isolated on saline-soaked laparotomy pads. Stay sutures are placed and an incision made in an avascular area. In the case of a mass removal or gastrectomy, the affected part of the stomach wall is removed. Closure is routine with a double layer inverting pattern (Mader *et al*. 2006, Alworth *et al*. 2011). Removal of foreign bodies from the stomach is also possible using endoscopy.

Enterotomy

Once the coelom is entered, the intestine is exteriorized. The colon (which is black in some lizards) can be used as a guide for recognizing the organs of the body cavity. The affected part of intestine is gently elevated and placed on saline soaked laparotomy pads to assess the extent of any pathological changes. Two absorbable fixation sutures are placed (Figure 28.6a) and the central part of the intestine wall is incised. Foreign body and faeces are gently withdrawn (Figure 28.6b) from the lumen and the mucosa is flushed with warm sterile saline. The wall of the intestine is closed with absorbable suture material in two layers. The first layer is a simple interrupted pattern and the second a continuous inverting pattern. The coelomic cavity is then carefully examined for any abnormalities. The coelom is then cleaned by repetitive irrigations with sterile saline solution and antibiotics.

Surgery of any of intestinal segment in larger lizards and snakes is usually uncomplicated; however, in chelonians it can be difficult. Complications arise particularly in the transverse colon and the functionality of the intestine after enterotomy cannot be always ensured. Enterotomy and colostomy (especially in the transverse colon) through the pre-femoral fossa is rather difficult, although in some aquatic chelonians it may be more accessible.

(a)

(b)

Figure 28.6 (a) Stay sutures placed in the intestine to assist surgical access. (b) Faeces are gently massaged out of the intestine through an enterotomy wound.

Complete or Partial Liver Lobectomy, Liver Biopsy

In snakes, the affected part of the liver is gently elevated out of the coelom cavity to assess any pathological changes. Temporary vascular clamps are placed cranially and caudally to the affected part of the organ. Ligatures are then placed allowing complete excision of the affected part of liver. Finally, the vascular clamps are released and occlusive ligatures tightened and examined. The cut surfaces of the remaining parts of the liver are rinsed with a sterile 0.9% sodium chloride solution to locate any bleeding.

In lizards and chelonians, an entire lobe can be removed if needed; the lobe is isolated and the blood vessels and bile duct double ligated and removed. The use of haemostatic clips can facilitate removal. Liver biopsy is performed as in other species via surgery (laparoscopy), minimal invasive surgery (endoscopy) or under ultrasound guidance.

Cystotomy

In most lizards, the bladder is readily elevated out of the coelom (Figure 28.7a,b,c). In chelonians, it can be accessed via a plastronotomy or though the pre-femoral fossa. The bladder wall is usually thickened if cystitis present. For small stone removal, retrieve with a lens loop or small forceps. Larger stones can be grasped and broken in situ if needed and the pieces removed. After the stone has been removed, the exteriorized bladder should be copiously flushed with sterile saline. A standard two-layer closure is generally recommended, then the coelom cavity irrigated with warm, sterile saline.

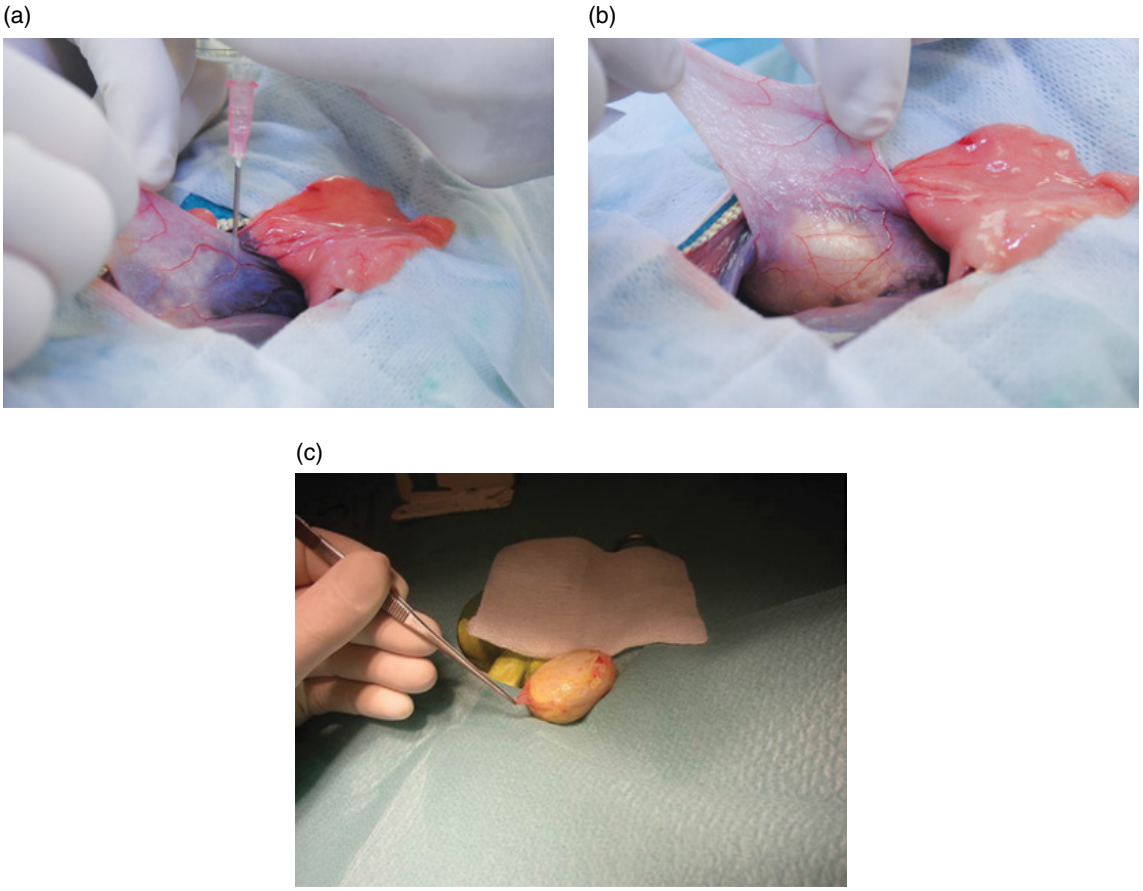


Figure 28.7 (a) Prior to cystotomy, urine is aspirated from the bladder. (b) The urolith is visible through the bladder wall. (c) Urolith surgically removed from the bladder of a tortoise.

Nephrectomy and Renal Biopsy

Nephrectomy is mostly straightforward in snakes and is usually indicated in cases of neoplasia. The kidney or mass is bluntly dissected out and the vessels supplying it and the ureter ligated and the kidney removed. In males, the seminiferous tubule may need to be bluntly dissected off and preserved (Vasaruchapong and Chanhome 2012). In lizards, the kidney is located within the pelvis, so complete nephrectomy is extremely difficult without transection of the pelvis and is not commonly performed. Endoscopy is the preferred method for obtaining biopsies but can also be obtained with a Tru-Cut device through a coeliotomy or an incision between the tail base and the rear leg in lizards.

Prolapsed Hemipene or Phallus

A prolapsed hemipene or phallus should be attended to as soon as possible, keeping the tissue moist, otherwise necrosis will occur. The prolapsed organ should be cleaned and any lacerations repaired. Tissue swelling can be reduced using sugar or other hypertonic solutions. The organ is then replaced and a horizontal mattress suture placed on either side of the cloaca. It is important to make the suture tight enough to prevent further prolapse but still allow the passage of faeces and urates. This suture can be removed after seven days. The underlying cause must be addressed and systemic antibiotics are indicated if infection is present. If necrosis is present or the hemipene or phallus has re-prolapsed multiple times, amputation may be necessary (Mader *et al*. 2006). For snakes and lizards with hemipenes, as long as one hemipene remains, the animal is still able to breed. To perform amputation, one or two transfixing sutures are placed at the base of the organ for haemostasis, the tissue transected and removed. The stump can be oversewn with a simple continuous suture if necessary. The tissue stump will usually retract easily into the cloaca. Postoperative antibiotics are recommended if there is evidence of infection.

Orthopaedic Surgery

Principles of Fracture Repair and Bone Healing

External coaptation, internal fixation and external fixation methods have all been used in reptiles. The method of repair is chosen based on the location of the fracture, the size of the patient, the ease of application and tolerance by the patient, the owner's ability to manage the patient postoperatively, financial concerns and the surgeon's comfort level. Complete healing from a traumatic fracture can take 6–18 months (although fixation is usually only needed for 6–12 weeks), although fractures due to nutritional secondary hyperparathyroidism (NSHP) seem to heal much faster, as long as the underlying problem is corrected. If significant damage to the soft tissues and vascular supply has occurred, amputation may be necessary.

External Coaptation

External coaptation involves the use of splints, slings or bandages to immobilize a fracture. Fractures with minimal displacement that are not compound tend to heal well with this technique. For patients with NSHP, this is the treatment of choice, as the bones are not strong enough to support additional hardware. The limb should be splinted in a normal walking position so that the patient can still ambulate and to avoid the potential for disuse atrophy or decreased range of motion in the joints after the bandage is removed. In lizards, a modified spica splint crossing over the pelvic or pectoral girdle to the limb on the opposite side can be used, particularly for fractures of the humerus and femur. This method keeps the limb in a normal position.

Alternatively, the pectoral limb can be pulled caudally and taped to the body or the pelvic limb taped to the tail. The disadvantage to this method is that the limb being held in extension but the results are usually acceptable. In small chelonians with a humeral or femoral fracture, the limb can be flexed up inside the shell and taped in place.

External and Internal Fixation

Intramedullary pins and cerclage wire are commonly used for internal fixation in smaller reptiles. Pins can also be tied in to an external skeletal fixator to provide additional stability. For external fixation, common injection needles or K-wires can be used, which are threaded transversely through the affected bone under and above the fracture and fixated from outside on both sides by an infusion tube filled with quick-setting cement or a lightweight casting material (Figure 28.8). In large chelonians, bone plates can be used to stabilize fractures of the long bones (Mitchell 2002). The same principles apply when using these techniques in reptiles as in other animals. Complications can occur such as premature pin loosening, infection, damage to joints, and so on. In the case of non-union fractures, bone grafts can be harvested and placed at the fracture site to stimulate healing. Grafts can be collected from the humerus, femur, a rib or the wing of the ilium.

Amputation

Tail

Tail necrosis is common in lizards and partial amputation of the tail is often required. A ring block with lidocaine or bupivacaine is performed or the procedure performed under sedation or general anaesthesia. The tail is cut straight through with a scalpel blade. Pressure is applied for haemostasis and the end of the tail is left open to granulate in, so that the tail can regenerate; the skin can be closed in patients without natural tail autonomy (for instance chameleons, bearded dragons, green iguanas). The end of the tail should be kept clean and dry and the patient kept on nonparticulate substrate until the wound heals. When the diameter of the tail is large, primary closure should be used.

Limb or Digit

Determining when to amputate a limb or digit is based on how the species will use the limb postoperatively; sometimes leaving a stump for ambulation is preferable.

Figure 28.8 Repair of a forelimb fracture in a chameleon using segments of infusion tube filled with quick-setting cement and fine pins.

Regardless of the site, enough soft tissue should be left to pad the end of the bone. A skin flap should be created ventrally so that, when the incision is closed, it will lie on the dorsal aspect of the limb and not on the walking surface; healing is not delayed and the possibility of contamination of the incision is greatly reduced (Mader *et al*. 2006, Alworth *et al*. 2011). In chelonians, the prosthesis can be placed on the ventral aspect of the plastron postoperatively so that the patient does not fall to one side when walking. It usually needs to be replaced over time. The amputation of digits can be performed at an interphalangeal joint leaving healthy tissue and the skin closed routinely.

Skull and Facial Bone Fractures

Common principles of fracture repair are used for fractures of the maxilla or mandible in reptiles (Mader *et al*. 2006, Alworth *et al*. 2011, Tuxbury *et al*. 2010). If enough normal bone structure remains, hypodermic needles can be used to drill holes. Cerclage wire is passed through the needle, the needle is removed and the wire tightened to stabilize the fracture (Figure 28.9a,b,c). The use of external fixators has also been described. A 'bridge' over a fracture site should be created using a fibreglass and epoxy patch as one would use to repair shell fractures.

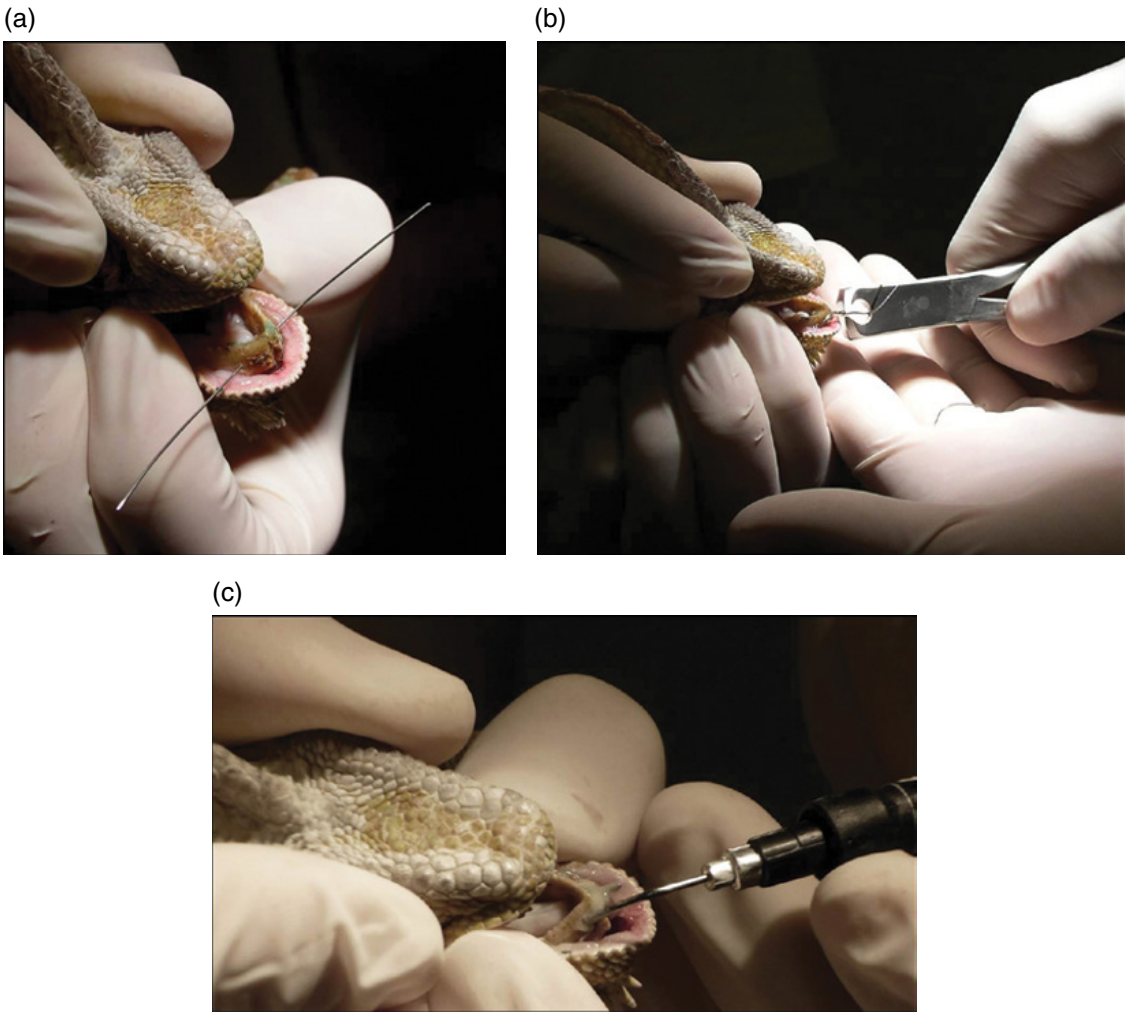


Figure 28.9 (a) Wiring of a mandibular symphysis fracture in a chameleon. (b) Gentle tension band wiring incorporating the transverse fixator. (c) Resin is applied to the sharp ends of the wires.

Venomoid Surgery

Owners of venomous species may request this surgery to make their venomous reptile less dangerous, but this reason must be actively discouraged. To provide such surgery is against the law, against the principles of animal welfare and unethical. Venomoid animals must still be treated as venomous for the safety of all involved and, in many Australian states these animals are legally still considered venomous (Johnson 2011). There may be limited situations where venomoid surgery is deemed appropriate. Once the snake is fully anaesthetized, the snake is placed in dorsal recumbency and the jaws are opened wide. An incision is made in the oral mucosa between the teeth and lip margin and the gland and duct are dissected out and carefully discarded. Sterile silicone prosthesis is placed in the surgical site and the mucosa closed with absorbable suture (Mader *et al*. 2006). After surgery, the snake is fasted for several weeks and must only be fed dead prey.

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