Small Mammals

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Common Surgical Procedures of Rodents, Ferrets, Hedgehogs, and Sugar Gliders

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KEY POINTS

- Surgical principles developed in dogs and cats can be directly applied to small mammals with some adaptations.
- Maintaining normal body temperature during prolonged procedures and minimizing blood loss are significantly more important in small mammals compared with dogs and cats.
- Key anatomic differences between small mammalian species must be known prior to performing any surgical procedure.
- Small mammal surgery requires knowledge of anesthetic techniques and application of appropriate analgesics.
- Common surgical procedures in small mammals include: integumentary mass and abscess excision, reproductive procedures (orchidectomy, ovariectomy, and ovariohysterectomy), gastrointestinal foreign body removal, prolapsed gastrointestinal tissues, urolith removal, and intra-abdominal mass excision.

INTRODUCTION

Developing skills associated with small mammal surgical procedures is important for clinical practice, whether in private/referral practice, a laboratory animal facility, or a zoologic institution. For quality veterinary care, it is important to understand not only anatomic and behavioral differences between species but also the most common clinical presentations for each small mammal species. This article describes common

surgical techniques in rodents, ferrets, hedgehogs, and sugar gliders. Surgical procedures discussed in this article include integumentary mass and abscess removals, wound management, self-mutilation, management of prolapsed tissues, gastrointestinal and hepatic surgery, reproductive and urinary tract procedures, and endocrine diseases.

PRESURGICAL CONSIDERATIONS
Anesthesia and Analgesia

Anesthesia of small mammals, especially rodents, hedgehogs, and sugar gliders, can be challenging, and although this article is not intended to provide detailed information or protocols for small mammal anesthesia, it is, nevertheless, important to highlight a few important points. There are several premedication and sedation protocols available in the literature for small mammals, but intubation can be difficult for anesthesia maintenance in most small mammal species.[1,2] The exception in this article is the ferret, which is easy to intubate, similar to intubating a small cat or kitten. Most rodent species and hedgehogs, however, require endoscopic intubation due to small oral cavities and obstructed view of the epiglottis.[3] Without access to endoscopic intubation techniques, most clinicians default to using a small facemask for gas anesthetic induction and maintenance. Placement of an intravenous (IV) catheter benefits any animal undergoing a surgical procedure, and this is especially true in small mammals. IV or intraosseous access facilitates fluid administration for maintenance and replacement in the face of blood loss and provides rapid correction of cardiovascular perturbations by use of appropriate cardiopulmonary stimulant drugs.[1,2] Small IV catheters (26 gauge to 23 gauge) can be placed in cephalic or saphenous veins of most small mammals and maintained during the procedure. IO catheters (eg, appropriately sized spinal needles or hypodermic needles) are most commonly placed in the proximal tibia or proximal femur. Appropriate anesthetic monitoring is critical during small mammal surgical procedures by use of a pulse oximeter, capnometer, ECG, and indirect blood pressure units. It is also important to monitor body temperature frequently, because low body temperature can cause markedly delayed, or lack of, postsurgical recovery. Use of circulating water heating pads, microwaveable heating devices, or Bair Huggers (3M, Corporation, St. Paul, MN, USA) for maintaining patient warmth should be considered imperative. Preemptive analgesia, or analgesics administered prior to induction of a painful stimulus, is crucial in small mammals, although the literature is sparse with specifics with respect to analgesic efficacy, dosages, duration, frequency of administration, and safety.[2,4–6] As with most nondomestic species, clinicians tend to extrapolate dosages from domestic mammals and hope there is some efficacy without detrimental side effects.

Surgical Preparation

Once an animal is appropriately anesthetized, maintained on monitors, provided supplemental warmth, and administered presurgical analgesics, and other medications, the hair around the surgical site can be clipped and the site aseptically prepared. Clippers and blades may need to be smaller than those typically used for dogs and cats, and some small mammals have delicate skin that is, easily traumatized by clippers. It is not uncommon for a surgeon to accidently begin an incision with a clippers if not careful. Surgical site preparation is similar to dogs and cats, with chlorhexidine or povidone iodine-based soaps used for cleaning, and alcohol or warm saline used to wipe away excess soap. Excessive removal of hair and application of alcohol contributes to rapid loss in body temperature. It is best to use clear, plastic drapes so that the patient can be easily observed and monitored during the surgical procedure. Gas

sterilized cling wrap is useful as a transparent drape for small species during surgery if a plastic drape is not available (Fig. 1). Care must be taken when placing towel clamps anchored onto the skin of small mammals, and it may be preferable to anchor the plastic drape to towels underneath the patient to minimize skin trauma. The size of surgical instruments should be small compared with those used in dogs and cats, such as using a mini-instrument pan or ophthalmic instruments for the smallest patients.

POSTSURGICAL CONSIDERATIONS

During recovery, continuing to keep the patient warm is imperative. Recovery in an incubator with constant body temperature monitoring is beneficial. Maintaining an IV catheter for the immediate postoperative period is important, as long as the animal is not attempting to chew at the catheter. Postsurgical analgesic use, including opioids and nonsteroidal anti-inflammatories, should always be anticipated.

COMMON SURGICAL PROCEDURES
Integumentary Surgery

The integumentary system is composed of skin and associated adnexa. Basic elements of the integument are similar across all mammalian species, but a few important, species-specific differences are worth highlighting when evaluated from a surgical perspective. For example, rather than hair, the hedgehog has spines, which must be plucked like bird feathers during presurgical preparation. Some species, such as chinchillas and sugar gliders, have very thin skin, especially in the inguinal or scrotal region; therefore, caution should be implemented when clipping and prepping this area to avoid iatrogenic trauma. On the other hand, the skin associated with the dorsal cervical region of ferrets can be thick and tough, whereas the abdominal skin of ferrets, in particular those with adrenal adenoma/adenocarcinoma, may be very thin. In some small rodent species, in particular hamsters, there is an abundant epidermis and dermis with significant elasticity, which can be of benefit when surgically closing an area with a significant tissue deficit. The skin of Guinea pigs, however, tends to be much less elastic, making it more difficult to close large surgical wounds. Common integumentary surgical procedures in small mammals include trauma (wound closure), epithelial or subcutaneous mass removal, and surgical débridement/excision of abscesses. Additionally, cheek pouch prolapse and diseases associated with scent glands are occasionally observed in hamsters.
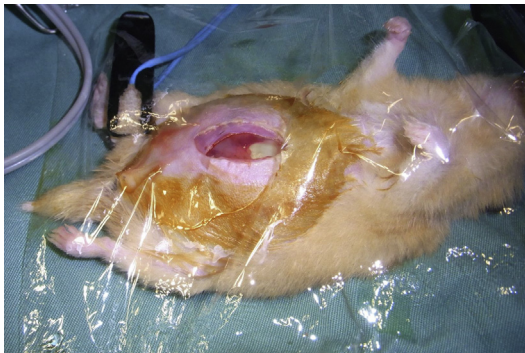

Fig. 1. Veterinary transparent drapes are used for small mammal surgeries. It is also possible to use gas sterilized commercial cling wrap as a transparent drape for small species during surgery.

Traumatic wounds

Trauma is common in small mammals and is associated with intraspecific or interspecific bite wounds (**Fig. 2**), being dropped by a human caretaker, wounds from cage material or cage ornaments, self-mutilation, or other accidental injuries when an animal has free access to their house environment.[7,8] Bite wounds from cage mates are commonly observed in rodents (see **Fig. 2**) and occasionally observed in ferrets. Interspecific bite wounds, especially from cats, frequently lead to fatal septicemia if not treated rapidly and thoroughly. Most traumatized small mammals should be evaluated for hemorrhage and blood loss and signs of infection and the body should be thoroughly examined for less obvious, hidden wounds. Severe hemorrhage resulting from trauma, such as lacerations of major vessels, hematomas, or internal organ damage, is frequently life threatening in small mammals, so immediate hemostasis and supportive care are critical. Sedation or anesthesia is typically necessary for small mammals that need to be evaluated after a traumatic incident. Generally, the hair associated with the skin lesion must be clipped to properly evaluate the wound. Once the hair is clipped, some wounds require suturing, whereas other wounds may heal over time by second intention with intensive bandage changes and wound débridement. Warm disinfectant solutions (eg, dilute povidone iodine or chlorhexidine) and/or saline may be necessary for cleaning large wounds to avoid heat loss. Appropriate use of analgesics, nonsteroidal anti-inflammatories, and antimicrobial drugs should be considered during treatment of traumatic wounds. The basic tenets of small animal (ie, dog and cat) wound management and secondary infection control can be applied to small mammals, except that choice of antimicrobials is based on safety for the species, in addition to microbial culture and sensitivity. Generally, most wounds heal by second intention if secondary infection is controlled, and surgical intervention is only required with open wounds with wide skin margin deflection or with very recent wounds with clean, underlying tissues. As an illustration of excellent second intention wound healing, a ferret was evaluated by one of the authors (YM) for significant inguinal skin sloughing secondary to urolith urethral obstruction and subsequent bacterial infection (**Fig. 3**). In this case, the wounds resolved over time using wet-to-dry bandages, antimicrobials based on bacterial culture and sensitivity, anti-inflammatories, and analgesics.

Abscesses

Abscesses are commonly observed as superficial lumps or masses, especially in rats, guinea pigs and other rodent species. Abscesses in small rodents are most commonly
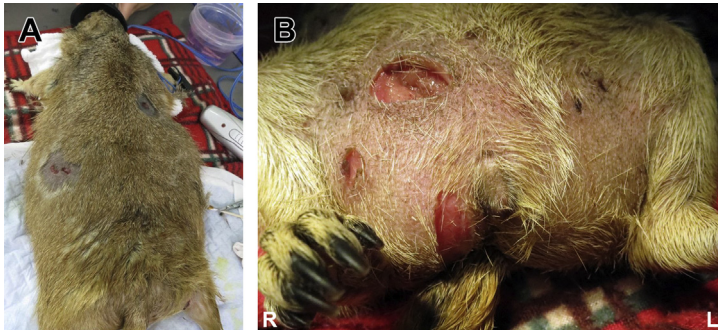

Fig. 2. Intraspecific bite wounds from cage mates in a prairie dog. These wounds were surgically closed after disinfection. (*A*) Dorsal view. (*B*) Ventral view.
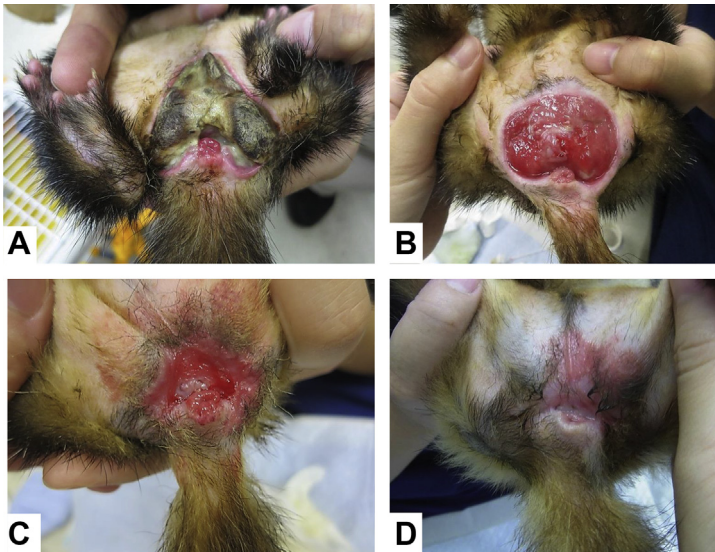
Fig. 3. An example of wound healing by second intention in a ferret. (*A*) First presentation, Day 1. (*B*) Day 9. (*C*) Day 21. (*D*) Day 30. A large area of inguinal skin sloughed secondary to a severe bacterial infection associated with urethral obstruction with urolithiasis in a ferret. The lesion healed by second intention with disinfection of the lesions and replacement of wet-to-dry bandages.

the result of bite wounds from cage mates.[9] Subcutaneous abscesses in rats are common and must be distinguished from mammary adenomas (**Fig. 4**). Initially, differentiating between a soft tissue mass and abscess is important through use of a fine-needle aspirate (FNA) and cytologic examination. Confirmed abscesses are typically obvious once the needle is inserted and purulent material is expressed from the needle insertion site. There are cases of neoplastic lesions, however, with purulent, necrotic cores that can be misdiagnosed as a pure abscess. With abscesses, collecting a sample for aerobic and anaerobic bacterial culture and antimicrobial sensitivity is an important next step. Managing abscesses can occur using 2 methods. First the animal must be sedated or anesthetized and the hair associated with the abscess clipped and the site aseptically prepared. One approach is to lance the abscess using a scalpel blade (#11 or #15); drain the purulent material; irrigate the abscess using warm, sterile saline, dilute chlorhexidine, or povidone iodine; and leave the incision open to heal by
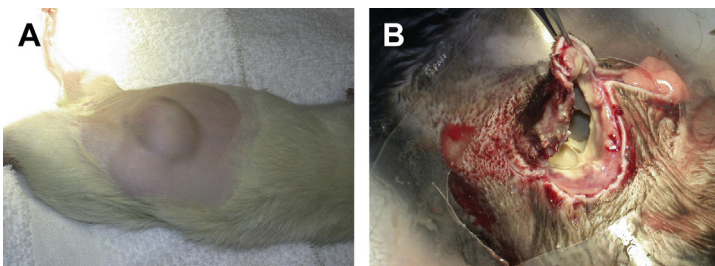

Fig. 4. (*A*) Subcutaneous abscess located on the ventrum of a rat. This was associated with a cage mate bite. (*B*) The abscess capsule and purulent material contained within are visible.

second intention. Administering appropriate antimicrobials is normal standard of practice in these cases. This approach to abscess management is usually curative in ferrets, sugar gliders, and hedgehogs. In other rodents (eg, Guinea pigs, chinchillas, hamsters, rats, and mice), however, recurrence is common if the abscess is not fully excised, without rupturing the capsule, because the abscess capsule remains a constant nidus of infection (Fig. 5).[9] Therefore, in rodents, the clinician should always consider surgical excision of the abscess, using an elliptical incision around the abscess and treating it is though it was a soft tissue mass. The skin can be closed using either suture material or staples but with awareness that many rodents, without placement of an Elizabethan-collar (E-collar), vigorously attempt to chew and scratch at their incision. Staples can help slow down the process of having a determined rodent open the surgical wound, and proper E-collar placement prevents access to the surgical site.

Pododermatitis
Pododermatitis is occasionally observed in Guinea pigs, chinchillas, rats, hamsters, hedgehogs, and rats (Fig. 6). Generally, surgical intervention is not necessary for mild to moderate lesions, and medical therapy includes the following approach: (1) soaking lesions with dilute chlorhexidine or povidone iodine solutions; (2) applying antimicrobial ointments/creams (eg, silver sulfadiazine) with overlying bandages and regular, repeated bandage changes (see Fig. 6); (3) maintaining the animals on soft substrates; and (4) administering appropriate antimicrobials, anti-inflammatories and analgesics. In severe cases of pododermatitis, particularly with radiographic evidence of osteomyelitis, surgical débridement and/or amputation of the affected limb may be necessary. With limb amputation of small mammals, it is usually best to amputate the entire limb, otherwise trauma to the remaining limb stump is a chronic, recurrent medical issue. Limb amputation in small mammals is identical to procedures described in dogs and cats, with an extra focus on hemostasis, analgesia, and warmth. Remarkably, rodents adjust rapidly to loss of a limb, except some Guinea pigs have a difficult time holding their body off the ground with 3 limbs, especially with loss of a forelimb. This can result in dragging of the body and trauma to the ventrum, so this must be considered prior to amputating Guinea pig forelimbs.

Self-mutilation
Self-mutilation is commonly observed in sugar gliders, and it is most common for them to self-mutilate the penis, inguinal region, and base of tail (Fig. 7). Although
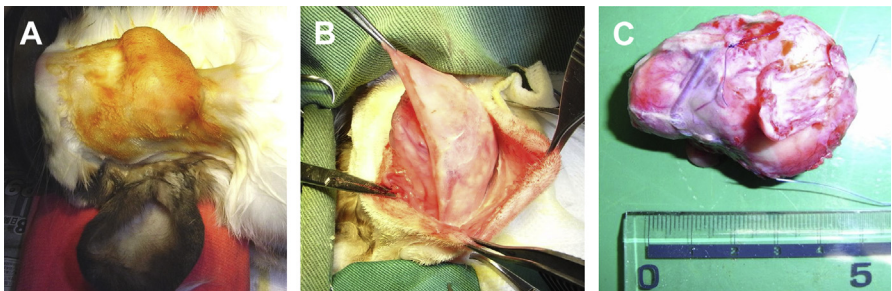

Fig. 5. This is an example of complete excision of an abscess in a rabbit. (*A*) Pre-surgical appearance of the mandibular abscess. (*B & C*) Recurrence is fairly common if the abscess is not excised without rupturing the capsule in rabbits and rodents because the abscess capsule continues to be a nidus of chronic infection and abscessation.

Fig. 6. Severe pododermatitis in a guinea pig. Lesions (*A*) are treated by soaking with dilute chlorhexidine or povidone iodine, applying silver sulfadiazine cream, and bandages (*B*) that are replaced once to twice weekly depending on how clean and dry the bandages are maintained. Appropriate oral antibiotics based on bacterial culture and antibiotic sensitivity, and anti-inflammatory drugs are administered. Bandaging with only elastic adhesive tape is difficult to keep clean, so latex or nitrile glove finger parts or duct tape are used to cover the outside of the bandage to keep clean and dry (*B*). These lesions were resolved within approximately 2 months by second intention healing (*C, D*).

understanding of behavioral mechanisms underlying this condition in sugar gliders is limited, hypotheses include, boredom, lack of appropriate conspecific social or sexual interactions, owner neglect, inappropriate environment and husbandry, and death or recent separation of cage mates.[10] Excessive chewing and self-mutilation of the
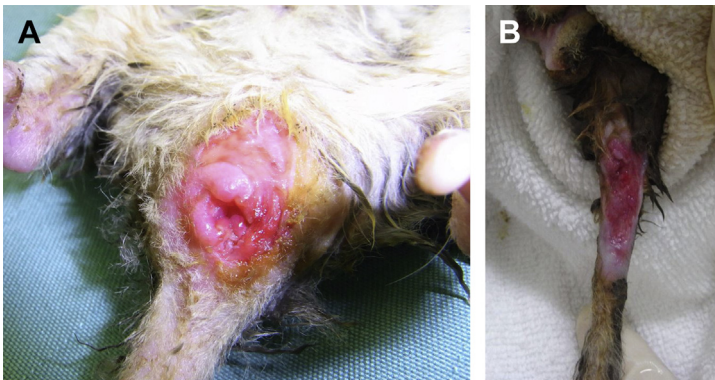

Fig. 7. Self-mutilation in a sugar glider. The most common sugar glider self-mutilation lesions are (*A*) inguinal areas and (*B*) the base of the tail.

perineal-cloacal region may be caused by pericloacal gland impaction/infection or penile prolapse.[10] In cases of tissue necrosis or severe tissue destruction, surgical repair is frequently necessary (**Fig. 8**), but most mild to moderate self-mutilation wounds heal by second intention along with appropriate antimicrobial and anti-inflammatory administration. When the penis is affected, amputation may be necessary (**Fig. 9**). Sugar gliders have a biforcated penis and urinate from the penile base, so amputation at the forked end of the penis does not interfere with urination (see **Fig. 9**). Early castration of sugar glider males is often recommended because sexual frustration may be a factor associated with self-mutilation (discussed later). In most cases, initial treatment involves hair clipping, disinfection of wounds with dilute povidone iodine or chlorhexidine, the use of antimicrobials and analgesics, and correction of the underlying causes, such as improper socialization, husbandry, nutrition, and so forth. Modified E-collars or Velcro (Velcro Industries, Manchester, NH, USA) and fleece straightjackets are usually necessary to prevent further mutilation during treatment (**Fig. 10**). It is important not to remove the E-collar or straightjacket too soon in the healing process; typically, the authors maintain the protective E-collar/jacket for a minimum of 2 weeks after the wound has completely healed and keep the animal in the hospital to watch for recurrence of self-mutilation for 3 to 6 hours after removing the E-collar/jacket. If this process is not properly maintained and monitored, recurrence of self-mutilation can be so severe that euthanasia or death of the sugar glider is the outcome.

Tail slip

Slip, or traumatic degloving of the tail skin, is occasionally observed in long-tailed rodents, such as degus, gerbils, and chinchillas (**Fig. 11**).[9,11,12] In these species, the skin of the tail is thin and can easily be torn from the underlying tissues by overzealous grasping of the tail or lifting the weight of the animal by the tail. Rather than grasping the tail, the individual should be manually restrained over the dorsal cervical region and the rest of the body supported with the other hand. In cases of tail skin degloving, surgical amputation of the remaining degloved tail is recommended.[9,11,12] Amputation

Fig. 8. Severe self-mutilation in a sugar glider. Most sugar glider self-mutilation wounds are small so that surgical intervention is not necessary, but large wounds require surgical intervention.
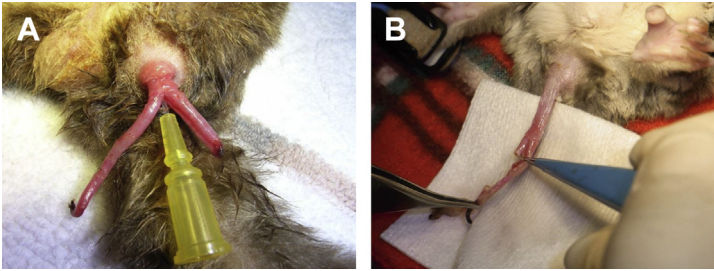
Fig. 9. Penile amputation in a sugar glider. (*A*) The urethral opening is at the bifurcation and this image shows a 24-gauge catheter inserted into the urethra. (*B*) Amputation of the bifurcated penis using bipolar cautery. Amputation at the forked end of the penis does not interfere with urination.
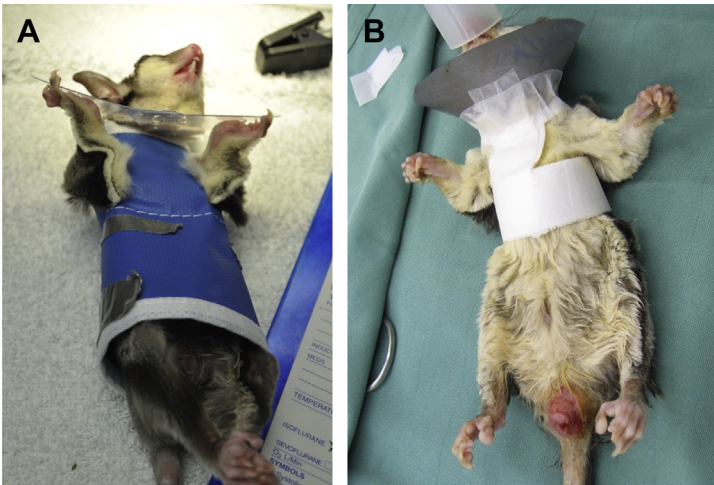

Fig. 10. Modified E-collar and 2 versions of the straightjacket used to prevent access to surgical sites in sugar gliders. Normal E-collars are easy to slip off. The connection of collar with jacket prevents this problem. (*A*) An E-collar modified into a straight jacket. (*B*) Using surgical tape as a bellyband.
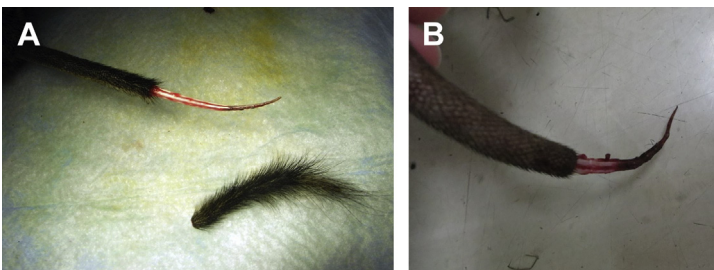

Fig. 11. Tail slip or degloving of the tail skin in (*A*) a degu and (*B*) a rat. This is common in chinchillas, gerbils, degus, and sometime rats and mice when a human grasps the tail and lifts the animal suspending the body weight by the tail. Degloving of the tail skin requires distal tail amputation.

is performed just proximal to the remaining skin margin. The hair associated with the amputation site is clipped, the distal tail is wrapped with aseptic gauze, and the amputation site aseptically prepared for surgery. A tourniquet placed at the very base of the tail aids with perioperative hemostasis. The procedure is nearly identical to that used for dog tail amputation. Once the site is prepped and draped, a local anesthetic, such as lidocaine, is administered around the planned skin incision site. A double V-shaped skin incision is made on right and left lateral aspects of the tail, just distal to the desired intervertebral transection site. Orient the double V-shaped incision to create dorsal and ventral skin flaps that are longer than the desired tail length; start the incision just distal to the desired intervertebral space. Bipolar cautery is useful for hemostatsis, and is critical in such a small working space. Muscles and subcutaneous tissue are bluntly dissected from the vertebrae caudal to the intervertebral transection site using small hemostats, and the distal tail is disarticulated with a scalpel blade (#11 or #15) by incising through the desired intervertebral space. Prior to closure, release the tourniquet at the base of the tail and observe the surgical site for hemorrhage. Use bipolar cautery if necessary to control remaining hemorrhage. Using 5-0 absorbable, monofilament suture material, appose subcutaneous tissues and muscles over the exposed vertebra with a simple continuous suture pattern. To close the skin layer, use 4-0 or 5-0 nonabsorbable, monofilament suture material in a simple continuous or simple interrupted pattern, making sure that there is enough skin to provide good apposition without tension. To protect the surgical site, it is best to place a light, pressure bandage over the incision and maintain the bandage in place for 24 to 48 hours. An E-collar may be necessary to prevent damage to the surgical site.

Tumors of the integument

A variety of skin and subcuticular neoplasms have been reported in small mammal species.[13–16] Based on the authors' experiences, skin and subcuticular neoplasms are common in hedgehogs, rats, ferrets, and hamsters and less common in guinea pigs and mice. Although integumentary neoplasms are uncommon in sugar gliders, with the exception of mammary gland tumors (Fig. 12), as sugar glider husbandry improves and captive age increases, it is likely that there will be an increased incidence of integumentary tumors. Of particular importance with respect to integumentary neoplasm incidence, squamous cell carcinomas are common in hedgehogs,[13] benign

Fig. 12. Mammary gland tumor in a sugar glider. Integumentary neoplasms are common in hedgehogs, ferrets, and hamsters but less common in sugar gliders. Arrow shows a mammary gland carcinoma in a sugar glider.

neoplasms of basal cell origin are the most common in ferrets,[13] and atypical fibromas are the most common in Djungarian (ie, dwarf) hamsters.[15] Djungarian hamsters show a high prevalence of neoplastic disease (5 times greater than Syrian hamsters), and most tumors are integumentary.[15] Neoplastic diseases are rare in chinchillas.[16] Mammary gland tumors, most commonly adenomas, are the most common subcutaneous tumor in rats and mice,[13,14] and the distribution of mammary tissue is extensive so the tumors can occur anywhere from head and neck to perineal region in both males and females (Fig. 13).[13] Diagnostic and surgical approaches with small mammal integumentary tumors are similar to those of dogs and cats; however, consideration of self-trauma is important after FNA of masses in some rodent species and sugar gliders. Additionally, hematoma-like lesions are occasionally observed in Djungarian hamsters, and appear as a flaccid, superficial mass (Fig. 14). These lesions can lead to life-threatening hemorrhage after FNA, so aspiration should be stopped immediately when blood is aspirated, and surgical removal of the lesion should be considered. The treatment of choice for integumentary tumors is complete surgical excision with histopathologic evaluation. Once the patient is prepped and draped, a scalpel blade or cautery device can be used to make an elliptical incision around the mass, or in cases of rat mammary masses, the incision is commonly made directly over the mass. Generally, little to no hemorrhage is observed if using a bipolar cautery forceps to incise the skin. Using a cautery device requires great caution to prevent ignition with oxygen used simultaneously during anesthesia. Additionally, application of other hemostatic aids, such as LigaSure (Covidien Surgical Solutions, Dublin, Ireland) laparoscopic instruments, contributes to reduction of operative time and minimizes hemorrhage. Making the elliptical incision to include appropriate surgical margins is important in any species, although large surgical margins may make closure more difficult due to the tension created during closure of the skin and subcutaneous tissues. When large epithelial defects are expected, the extent of the incisional line should be decided based on the anticipated skin tension and location of subdermal vascular plexus to avoid circulatory compromise after wound closure. These considerations are especially important for guinea pigs, because their skin is thick and less elastic compared with other rodent species, and Guinea pig integumentary tissues tend to develop a significant inflammatory reaction to excessive suture materials and skin tension compared with other small mammal species. Therefore, surgical wounds may be more likely to either dehisce or develop abscessation with tension
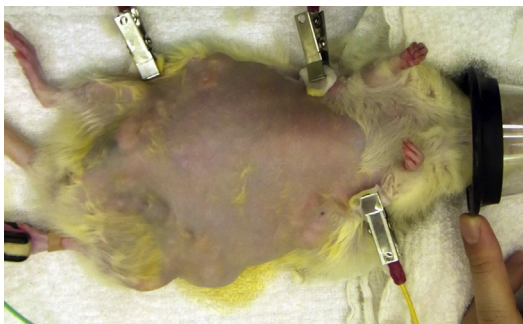

Fig. 13. Mammary adenoma in a rat. Mammary gland tumors are the most common subcutaneous tumor in rats. The distribution of the mammary tissue is extensive so the tumors can occur anywhere from neck to inguinal region in rats and affect both males and females.

Fig. 14. Hematoma-like lesion in a Djungarian (dwarf) hamster. Hematoma-like lesions (*arrows*) are occasionally observed in Djungarian hamsters as a flaccid superficial mass, and these lesions may lead to severe hemorrhage after FNA, so care should be taken when aspirating such masses.

or excessive suture material. For any small mammal species, such skin tension can be relieved by undermining skin adjacent to the surgical wound through blunt dissection, with care to preserve the subdermal plexus and direct cutaneous vessels that run parallel to the skin surface. If these methods do not allow primary skin apposition, the remaining surgical wound may be allowed to heal by second intention, or reconstructive surgical procedures, using skin flaps or grafts, can be completed with approaches as those used in dogs and cats. For rat mammary tumors, once the incision is made directly over the mass, the subcutaneous tissues can be undermined and bluntly dissected away from the mass using hemostats. Mammary masses in rats are well vascularized, so be careful not to incise the mass. Most typically, the mass can be freed from the subcutaneous layers, and the primary vascular supply can be for at the deep base of the mass. Ligatures or Hemoclips (WECK Hemoclip Plus, Teleflex Medical, Research Triangle Park, NC, USA) can be used to clamp the vessels supplying the tumor and the mass can be removed. Once any integumentary mass is removed from a small mammal, routine closure techniques are similar to those used in dogs and cats, closing the subcutaneous tissues with 3-0 to 5-0, monofilament, absorbable suture materials, and 3-0 to 4-0 monofilament, nonabsorbable suture material for closing the skin layer. Alternatively, skin staples may help in those species most likely to chew their incision, and are easy to apply and faster to apply than sutures. In Guinea pigs, skin staples can reduce the amount of foreign suture material, which is inflammatory in this species. Rat mammary tumors are likely to recur, so this should be part of the client communication.

Male and female Guinea pigs have an equal prevalence of mammary gland tumors, unlike most other species.[13,16] Guinea pigs have 2 mammary glands located just cranial to the inguinal region. Affected mammary glands expand in a solid or cystic manner and often secrete fluid, which has a plasma-like appearance. In these cases of mammary tumors, unilateral mammary resection is most common, because the right and left mammary glands are not physically associated with each other. It can be difficult to remove the entire mass or masses with clean margins, and postsurgical dehiscence is common. Resection of large masses requires deep subcutaneous sutures to minimize dead space and to limit incisional tension.

Cheek pouch eversion in hamsters

Many small mammal species have cheek pouches, which may be located internally within the caudal oral cavity, and may be large and expansile for storing food, or externally in some rodent species. Cheek pouch eversion is occasionally observed in hamsters, especially Djungarian hamsters.[9] Causes of hamster cheek pouch eversion include inflammation associated with a food item or foreign material, and microbial infection or abscessation. Clinically, the prolapsed cheek pouch is visibly hanging outside of the oral cavity and may appear swollen, erythematous, and edematous, with necrosis associated with prolonged cheek pouch tissue prolapse (Fig. 15). In acute cases, without severe edema or necrosis, management includes sedation, removal of food or foreign materials from the pouch, and replacement to its normal anatomic conformation using moistened cotton-tipped applicators. If there is concern about reprolapsing, a single, full-thickness, percutaneous mattress suture, using 4-0 or 5-0 monofilament, nonabsorbable suture material can be placed into and through the cheek pouch. In this case, the suture can remain in place for several days to 1 week, at which time the suture should be removed. If the prolapsed cheek pouch is moderately to severely edematous, 50% dextrose solution can be applied directly to the tissue, with the hope that the sugar solution will contribute to tissue contraction, allowing the cheek pouch to be replaced with moistened cotton-tipped applicators. If the prolapsed cheek pouch is severely inflamed or discolored or the mucosal tissue appears necrotic, the necrotic tissue should be surgically excised (see Fig. 15). Two stay sutures, using 4-0 or 5-0 monofilament, absorbable material can be placed proximal to the planned incision line. The tissue can be transected, circumferentially, just proximal to the necrotic tissue, and the excised tissue placed in buffered formalin for histopathologic analysis and a second piece used for bacterial culture if necessary. Care should be taken if placing
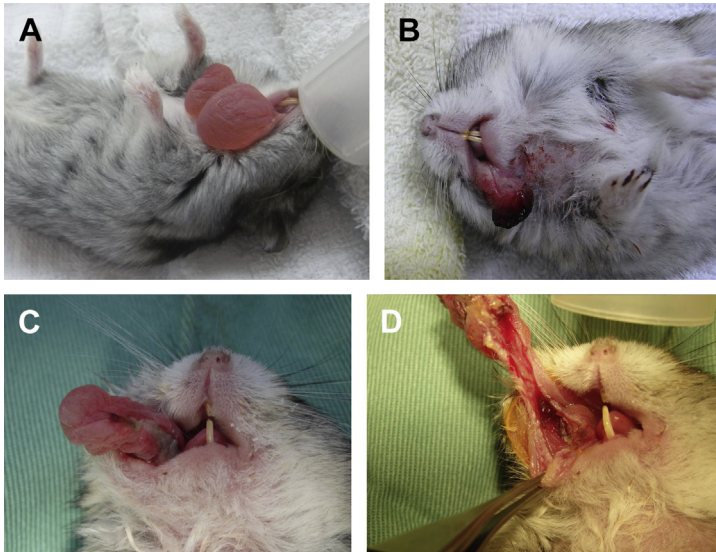

Fig. 15. Cheek pouch eversion in Djungarian hamsters. Typically, the prolapsed cheek pouch is (*A*) edematous, (*C*) inflamed, and (*B*) necrotic. (*D*) The necrotic portion of the everted cheek pouch can be surgically removed, sutured, and placed back in normal position.

hemostats or using forceps for firm manipulation of prolapsed cheek pouch tissue, because this can cause additional damage to remaining healthy tissue. The incision can be sutured using 5-0 or 6-0 monofilament, nonabsorbable suture material in a simple continuous pattern. Have bipolar or unipolar cautery instruments ready in anticipation of hemorrhage. Postoperatively, it is important to counsel the owner about avoiding food (eg, cooked pasta or rice) and bedding (eg, Kleenex) materials that are likely to adhere to the suture line and contribute to further problems. Additionally, the owner should be instructed to withhold the normal diet, and, instead, syringe-feed a fine-grind feeding formula for 3 to 5 days, and to remove all bedding materials that the patient may attempt to pack into the pouch, which can result in incisional dehiscence.[9] Appropriate antimicrobials and nonsteroidal anti-inflammatory drugs are administered for 5 to 7 days, postoperatively.

Intra-abdominal surgical procedures

Common, nonreproductive, intrabdominal surgical procedures of small animals include gastric or intestinal foreign bodies, hepatocystic diseases, proliferative lesions in abdomen (neoplasms, abscesses, granulomas, and so forth), urologic diseases (eg, uroliths), and rectal prolapses in hamsters and ferrets.

Gastrointestinal tract surgery

The most common surgical procedure of gastrointestinal system is removal of gastrointestinal foreign bodies in small mammals, especially ferrets.[17] Occasionally, it is necessary to collect small intestinal biopsy samples to diagnose underlying causes of chronic diarrhea in ferrets, or surgically excise intestinal tumors and repair intestinal intussusceptions. Preoperative imaging is critical for localizing lesions. During gastrointestinal surgical procedures, the surgeon should consider wearing magnifying surgical loupes. The surgical approach to all gastrointestinal procedures in small mammals is via a ventral midline incision.

Gastrointestinal foreign bodies

Gastrointestinal foreign bodies are occasionally observed in ferrets but are less common in rodents, hedgehogs, and sugar gliders. In a case of one of the authors (YM), an enterolith in a chinchilla was treated by, but this is rare. In ferrets, foreign bodies are most commonly ingested objects from the environment, but there are cases of trichobezoars in ferrets as well. Ingested foreign bodies tend to occur most commonly in younger ferrets, because they are inquisitive and like to chew on various objects, in particular rubber or sponge products (Fig. 16).[17–19] In contrast, trichobezoars tend to occur in older ferrets.[17] In cases of trichobezoars, there is usually 1 hairball, which is a comma-shaped, but sometimes 2 or multiple hairballs are found in the stomach and/or small intestine. The clinical presentation of ferrets with partially or completely obstructive foreign bodies includes regurgitation, anorexia, dehydration, lethargy, and melena. Diagnosis of gastrointestinal foreign bodies is based on history, physical examination, and imaging using radiography, CT, or ultrasound. Careful palpation of the ferret abdomen is important, because many gastrointestinal foreign bodies are palpable, and palpation commonly elicits a painful response, such as rapid hunching or vocalization. Abnormal radiographic abdominal findings include segmental ileus, gaseous distention of the stomach, and, occasionally, a visible foreign body. Gastrointestinal contrast studies can be conducted and may be useful in determining the location of the foreign body. Only 30% of foreign bodies, however, were detectable in a study evaluating contrast radiography in ferrets.[19] Supportive care and stabilization of debilitated ferrets with fluid therapy, analgesics, and proton pump inhibitors (eg, omeprazole) or H_2-receptor antagonists (eg, famotidine or ranitidine) may be
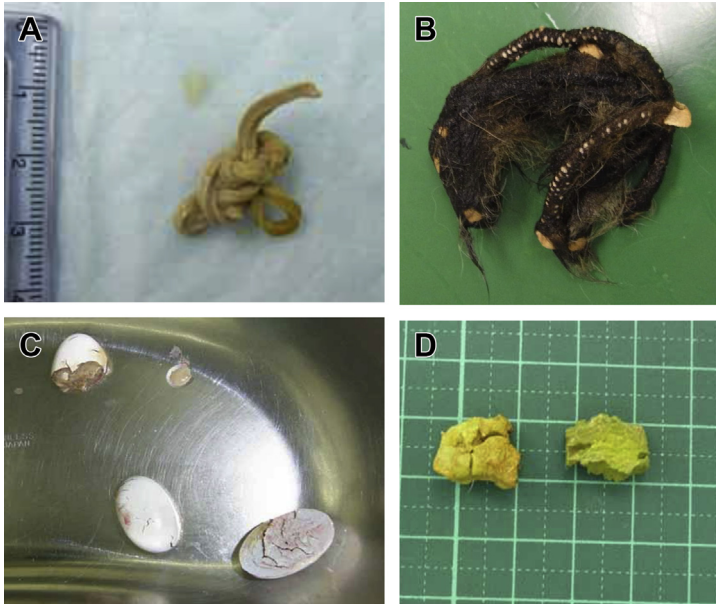
Fig. 16. A variety of foreign materials removed from ferret gastrointestinal systems. (*A*) Rubber band. (*B*) Hair elastic band. (*C*) Rubber toy. (*D*) Pieces of an eraser. Young ferrets tend to chew and swallow objects, especially those with rubber or soft foam.

useful to prevent gastritis and enteritis during anorectic perioperative period. Gastrointestinal foreign bodies can be removed surgically or by endoscopy. Small foreign materials in the stomach can be removed using a flexible endoscope of appropriate diameter, but larger foreign materials, and most trichobezoars, need surgical intervention. An advantage to using a surgical approach is that concurrent diseases associated with other abdominal organs, such as the pancreas, liver, intestines, and adrenal glands, can also be grossly evaluated during the procedure. Surgical procedures are similar to those of dogs and cats, except the authors avoid using hemostats to manipulate tissues, thereby avoiding iatrogenic trauma of delicate small mammal stomachs and/or intestines (Fig. 17). Once the location within the gastrointestinal tract is determined, a midline abdominal incision is made, which should be closely associated with the site of the lesion. The organ (stomach or small intestine) involved can be manipulated into the incision and 2 stay sutures can be placed in the serosal surface. Once the lesion, foreign body, or biopsy site is isolated outside of the abdomen, gauze moistened with sterile saline can be used to pack off the abdomen to prevent gastrointestinal content leakage. The stomach or intestine can be incised, biopsied, or resected and anastomosed using identical techniques in dogs and cats. Once the mass, foreign body, or biopsy tissue has been removed, single enterotomy or gastrotomy incisions should be closed in 2 layers, using 4-0 to 6-0 monofilament, absorbable suture material in an inverting pattern (eg, Cushing-Connell or Cushing-Lambert). Anastomoses can be closed in 2 layers, using 4-0 to 6-0 monofilament, absorbable suture material in an inverting pattern as well. The muscle layer is closed using 3-0 to 4-0 monofilament, absorbable suture material in a simple continuous pattern. The skin can be closed using an absorbable suture material in a subcuticular pattern or a nonabsorbable suture material for placing simple interrupted sutures. Skin staples are an alternative and are particularly useful if a clinician is aware that the patient
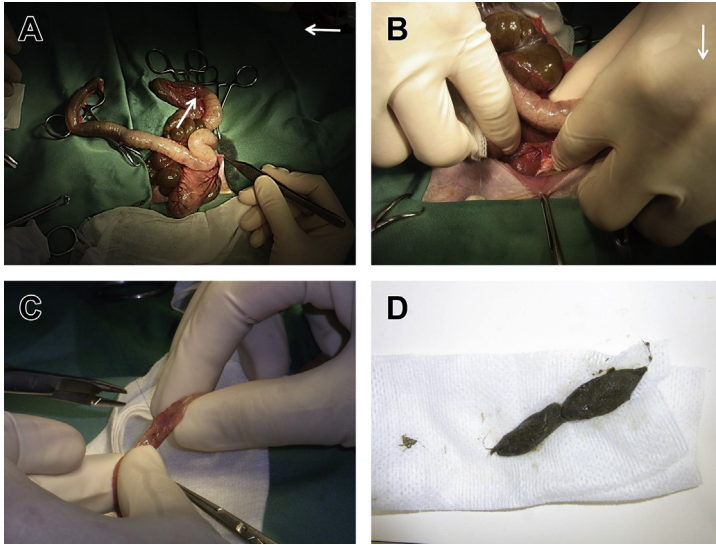
Fig. 17. Surgical removal of a trichobezoar in a chinchilla (*A*). To avoid iatrogenic trauma by using hemostats, the authors prefer to have an assistant hold the intestines of small mammals during enterotomy surgery (*B, C*). A trichobezoar was removed (*D*). *Arrow* indicates craniad.

chews at its incision site postsurgery. In most cases, recovery is rapid after gastrointestinal foreign body removal, and ferrets are able to eat soft foods within one or 2 days after surgery.

Proliferative abdominal lesions in (neoplasms, abscesses, and granulomas)

Neoplasms, abscesses, and granulomas can be found as proliferative lesions in the abdomen of small mammals and associated with 1 or multiple organ systems.[9,16,17,19] Intra-abdominal neoplastic diseases include uterine neoplasms in rodents and hedgehogs; adrenal adenoma/adenocarcinoma and lymphoma and pancreatic beta cell tumors (ie, insulinoma) in ferrets; neoplasms of liver and small intestines, which are occasionally observed in ferrets; uterine and kidney tumors in hamsters; and female reproductive tumors in guinea pigs; among others. Surgical procedures are similar to those performed in dogs and cats, with a ventral midline approach (as discussed previously). Attention must be paid, however, to shorter surgical times, hemostasis, maintenance of body temperature, and gentle tissue handling in small mammals.

Intra-abdominal abscesses are occasionally observed in ferrets and Djungarian hamsters. The cause of many of these abscesses is normally undiagnosed, except for those cases in which foreign material (eg, hay wood fibers) penetration of the gastrointestinal tract is observed. Complete surgical excision of the abscess with capsule is the most effective, but it is occasionally difficult due to development of significant tissue adhesions. In these cases, incise the capsule of abscess and remove as much purulent material as possible and irrigate with dilute antimicrobial solutions, followed by resection of as much of the abscess capsule as possible. The abscess capsule should be submitted for aerobic and anaerobic bacterial culture and cytology, and broad-spectrum antibiotics should be administered until receiving the bacterial culture and sensitivity results.

Intra-abdominal granulomas are occasionally observed in ferrets.[18,19] Treatment includes complete or partial excision or biopsies of the granuloma, followed by submission for cytology, histopathology, and or bacterial and fungal culture. In the authors' experiences, most intra-abdominal granulomas in ferrets are associated coronavirus or mycobacterial infection. In ferrets infected with coronavirus, granulomas are commonly found at the mesenteric lymph node (Fig. 18) but can also be disseminated in multiple organ systems (see Fig. 18).

Rectal prolapse
Although rectal prolapses can be observed in many small mammal species (Fig. 19), the incidence is greatest in ferrets and hamsters.[9,17–19] Young ferrets with chronic diarrhea are especially prone to rectal prolapses, which are generally superficial and typically resolve with treatment of the underlying cause of diarrhea. Prolapses in hamsters are also common but tend to be more severe and may include the rectum and large and small intestines. Additionally, in hamsters, intestinal prolapse can be accompanied by intestinal intussusception. Treatment of rectal prolapses in small mammals depends on severity and integrity of exposed tissues. In ferrets, treatment generally includes sedation or anesthesia, lubrication, and gentle replacement of the prolapsed tissue using cotton-tipped applicators, followed by placement of 2 transanal sutures using 3-0 to 4-0 nonabsorbable, monofilament suture material (Fig. 20), making sure that the animal is able to defecate normally. If the prolapsed lesion is severely edematous, 50% dextrose or Preparation H (Pfizer, Inc., Kings Mountain, NC, USA) can be applied to the prolapsed tissues prior to attempted replacement, as discussed previously. The underlying cause of the diarrhea must be addressed immediately as well, and the sutures can remain in place for 3 to 7 days. In cases of multiple rectal prolapse recurrence after addressing the underlying condition, a colopexy can be performed (Fig. 21). If the rectal mucosa is significantly and chronically everted and no
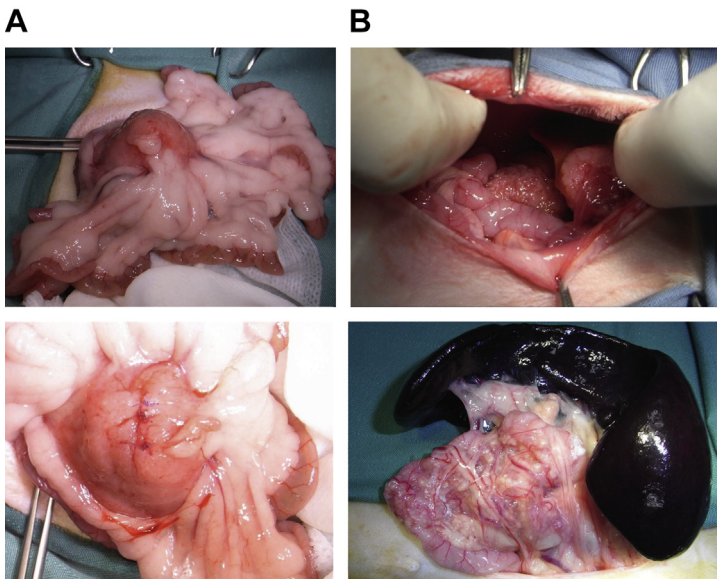

Fig. 18. Granulomas in ferrets caused by coronavirus infection. (*A*) Most ferret granulomatous diseases are associated with a single granuloma, (*B*) but a disseminated granulomatous pattern is occasionally observed.

Fig. 19. Appearance of rectal prolapses in (*A*) a ferret and (*B*, *C*) hamsters. Ferrets are more commonly prone to rectal mucosal prolapses, whereas hamsters are more commonly prone to large intestinal prolapses; (*B*) hamster with a rectal prolapse, and (*C*) hamster with a colonic prolapse.
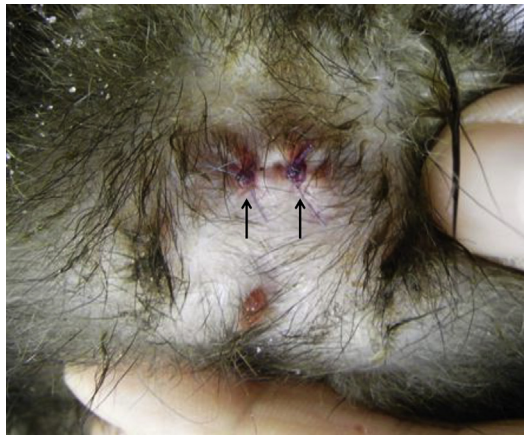

Fig. 20. Treatment of acute rectal prolapse in ferrets. Lubricate and gently replace the mucosa into its normal location using a moistened, cotton-tipped swab, then place 2 transanal sutures (*arrows*). The sutures should close the anus enough to maintain the reduced prolapse without interfering with passage of stool. These sutures can be removed after 3 to 7 days.
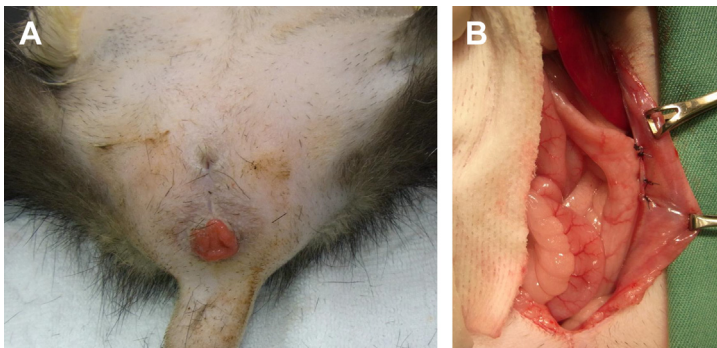

Fig. 21. Colopexy as a treatment of chronic, recurrent rectal prolapse in a ferret. (*A*) Presurgical appearance of the lesion and (*B*) intraoperative image of a colopexy.

longer reducible, the prolapsed tissue can be resected and the rectum sutured to the anus (Fig. 22). This procedure, however, may cause permanent anal sphincter atony. In hamsters, rectal prolapses tend to be more significant than those of ferrets (see Fig. 19) and include tissues proximal to the rectum, with some cases accompanied by intestinal intussusception (Fig. 23). Tissue discoloration and necrosis begin within several hours of the prolapsed tissue, and the affected hamster may be systemically compromised and require intensive supportive care along with urgent surgical repair. With necrosis, the tissue must be excised and the viable tissues anastomosed using 5-0 to 7-0 monofilament, absorbable suture material. An exploratory celiotomy is usually indicated if an intestinal intussusception is diagnosed, although the prognosis for these cases is poor. A routine, ventral midline abdominal celiotomy is performed, and the intussusception identified. Resection and anastomosis of the intestine is the typical approach, although there is evidence that if the intestinal tissues are viable, the intussusception can be reduced manually. With resection and anastomosis, use 5-0 to 6-0 monofilament, absorbable suture material to suture the proximal and distal ends of the intestine as in dogs and cats.

Hepatic Surgery

A surgical approach to the liver of small mammals is indicated for performing liver and gall bladder biopsies and surgically excising primary neoplastic masses and other hepatic diseases. Surgery of the extrahepatic biliary system is uncommon, but one of the authors (YM) has surgically managed several cases of extrahepatic biliary system obstruction in ferrets (Fig. 24). Surgical procedures associated with the liver are common in ferrets (Figs. 25 and 26) and prairie dogs, primarily for biopsies or tumor
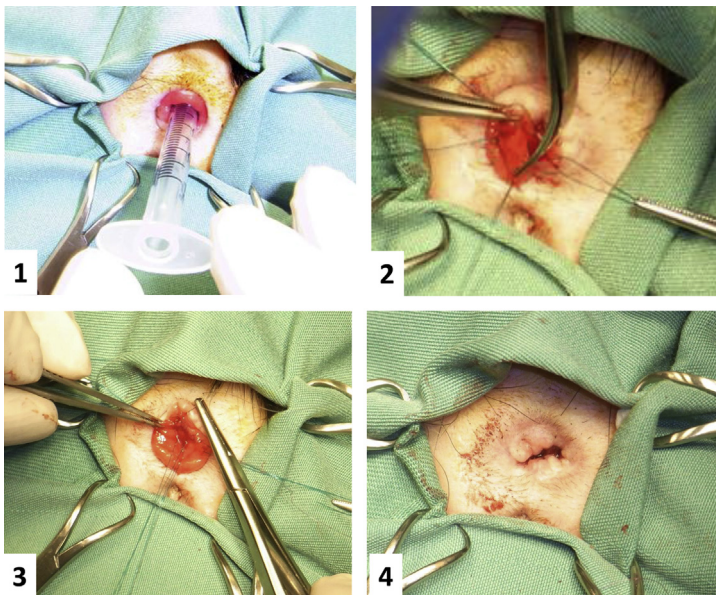

Fig. 22. Treatment of recurrent or severely everted rectal prolapse in ferrets: (1) prolapse reduction can be facilitated using a 1-mL syringe or moist swab, with confirmation of the excessive mucosa; (2) place 3 to 4 stay sutures in the rectal wall and resect the excess mucosa; (3) appose the edges with a continuous suture pattern using 6-0 monofilament absorbable suture material; and (4) postoperative appearance.
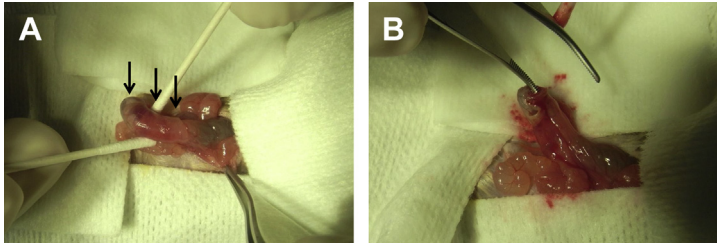
Fig. 23. Intestinal intussusception accompanied by rectal prolapse in a Syrian hamster. (*A*) Intraoperative image, region of intestinal intussusception area (*arrows*); (*B*) confirmation of the distal and proximal ends of the resected intestine.

excision, and less common in rodent species. Clinical signs associated with hepatic disorders are typically nonspecific until the disease process has advanced, and this may exacerbate the risk of anesthesia, because there may be impaired drug metabolism and excretion and prolonged duration of action of anesthetic drugs. These risks are more profound when injectable agents are administered, so a thorough pre-surgical evaluation of blood parameters and imaging techniques is imperative if severe hepatic dysfunction is suspected. Therefore, inhalational anesthetic agents are preferred for maintaining anesthesia in patients undergoing hepatic surgery, because isoflurane and sevoflurane have not been associated with postoperative hepatic dysfunction.[20] Hypoalbuminemia, or albumin levels less than 2.0 g/dL, may contribute to delayed wound healing and decreased synthesis of clotting factors may contribute
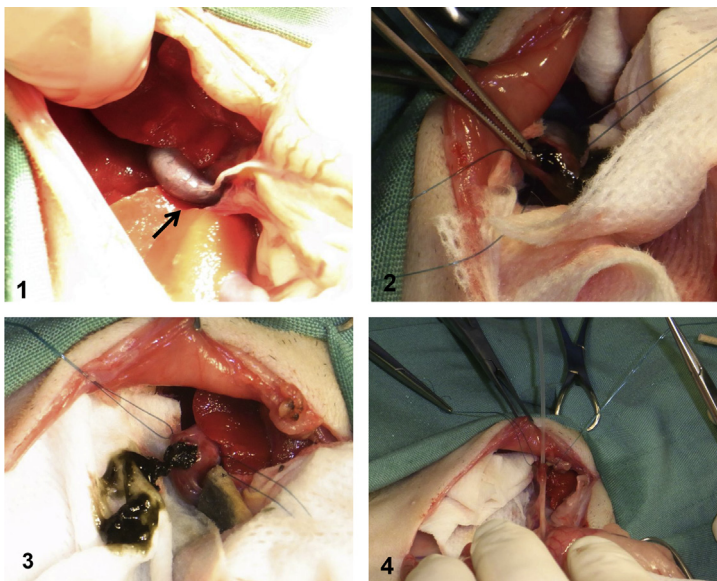

Fig. 24. Surgery for extrahepatic biliary system obstruction in a ferret: (*1*) markedly dilated common bile duct (*arrow*) with biliary sludge; (*2*) place stay sutures in the bile duct then make an incision in the duct wall; (*3*) remove the bile duct contents; and (*4*) confirm no obstruction using catheter and saline flush, and suture the incisional line with 5-0 to 6-0 absorbable suture material.
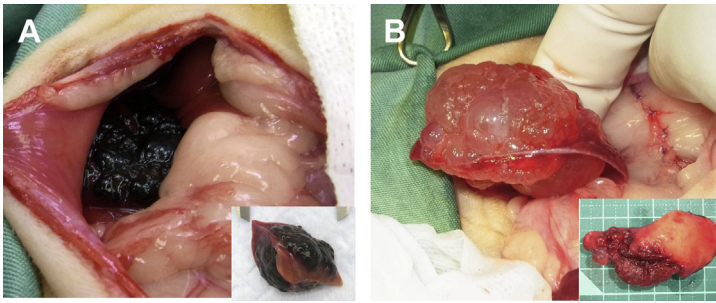
Fig. 25. Cystic hepatic lesions in ferrets. (*A*) Liver cyst and (*B*) biliary cystadenoma. Liver cystic lesions are occasionally observed in ferrets and can be surgically removed as shown.

to coagulopathies.[20] In these patients, preoperative blood transfusions and vitamin K should be considered.

The general approach for any hepatic surgery in small mammals is similar to techniques in dogs and cats, that is, make a cranioventral, midline abdominal incision, identify the section of liver of concern, and biopsy or excise the lesions. Cautery and absorbable hemostatic materials, such as Gelfoam (Pfizer, New York, NY, USA) and Surgicel (Ethicon), are also useful when performing hepatic surgery. Suturing of the abdominal muscles and skin is discussed in previously.

Hepatic Biopsy

Biopsy of the liver is indicated for prolonged liver enzyme elevation, observed ultrasonographic lesions, previous nondiagnostic cytology, diffuse hepatic diseases, and nonresectable, large hepatic tumors.[21] There are multiple techniques for collecting biopsy samples of hepatic tissues, loop guillotine suture (**Fig. 27**), punch biopsy, or stapling methods and partial lobectomy. The guillotine method is adequate for sampling the outer margin of the liver, whereas a skin punch biopsy is ideal for collecting a sample from a local lesion within the central portions of the liver. As with liver biopsies in
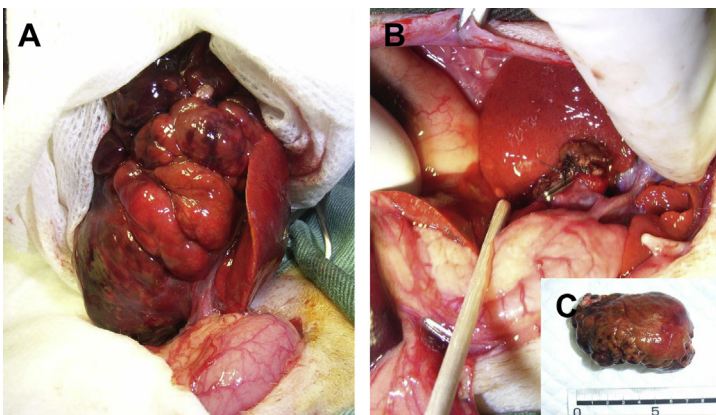

Fig. 26. Hepatocellular carcinoma in a ferret. (*A*) The mass was localized to 1 liver lobe. (*B*, *C*) Treatment of a solitary tumor is partial or complete liver lobectomy using a thoracoabdominal stapler.
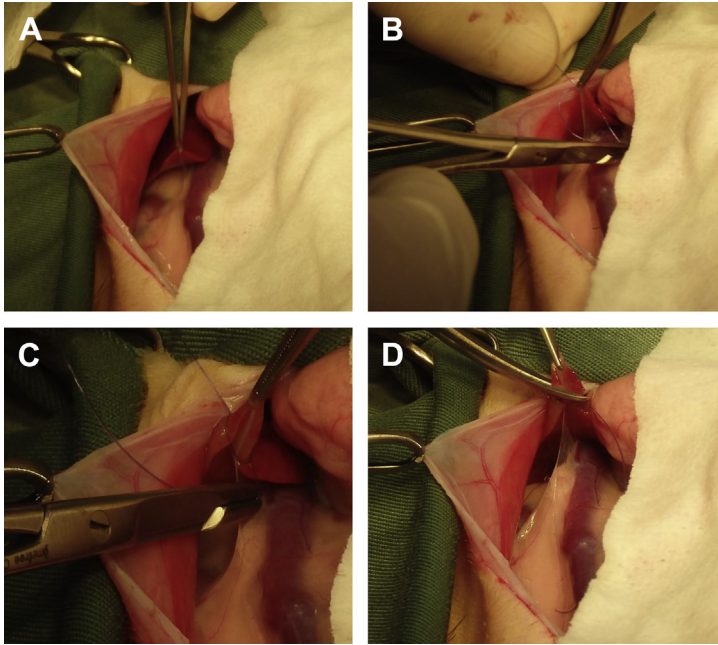
Fig. 27. Guillotine method for liver biopsy: (*A*) hold the tip of a liver lobe; (*B*) place a loop of suture around the protruding margin of a liver lobe; (*C*) ligate using suture to crush the hepatic parenchyma; and (*D*) cut the hepatic tissue distal to the ligature.

dogs and cats, at least 2 to 3 samples should be obtained from separate liver lobes, including both peripheral and central locations as well as grossly normal and abnormal-appearing tissue.[21] This approach may be difficult to impossible, however, for smaller species. Therefore, the authors recommend obtaining 1 to 2 samples, attempting to include both grossly normal and abnormal-appearing tissue. Once the biopsies are collected, rapid hemostasis using Gelfoam or Surgicel is critical. Decreased clotting factors may contribute to difficulty stopping the hemorrhage associated with a biopsy site.

Hepatic Lobectomy for Mass Removal

Liver neoplasms may be primary or secondary metastatic lesions and are occasionally observed in older ferrets and prairie dogs, and most patients present with or without overt clinical signs. Surgical treatment of a solitary tumor is partial or complete liver lobectomy, and liver biopsy or tumor debulking surgery for diffuse neoplastic diseases. Again, hemostasis is extremely critical in small mammal patients.

Surgery of the Spleen

The spleen is located in the left cranial abdominal quadrant of all small mammals, and it varies in size and shape among species. Surgical conditions of the spleen include laceration, torsion, neoplasia (primary and metastatic), and hematoma. For small mammals, however, splenic diseases, especially neoplastic masses, are primarily observed in ferrets. Generalized splenomegaly is common in ferrets, and many clinicians, wrongfully, decide to collect an FNA or biopsy only to receive a diagnosis of

extramedullary hematopoiesis.[18,22] In most ferrets with generalized splenomegaly, biopsy and surgery are not indicated, except with severe splenic enlargement that interferes with abdominal visceral function or a ferret's activity (Fig. 28). Other causes of ferret splenic enlargement, such as cardiomyopathy, Aleutian disease, and eosinophilic gastritis, have been reported.[22] Additionally, isoflurane anesthesia causes splenic sequestration of red blood cells and the reduction of hematocrit by up to 35% in ferrets.[23] Thus, ferrets with splenomegaly should always be evaluated for underlying disease conditions, and splenectomy should only be considered with ultrasonographic or CT evidence of splenic surface or parenchymal irregularities. The most common indications for considering a splenectomy include, neoplastic diseases (primary or metastatic), and traumatic laceration of the splenic capsule in ferrets. In ferrets, lymphoma is the most common primary splenic neoplastic disease, and hemangiosarcoma, mast cell tumor, and liposarcoma are occasionally observed as primary splenic neoplasia. Metastatic diseases are most commonly associated with adrenal neoplasia or pancreatic beta cell tumors (ie, insulinoma). Laceration of the splenic capsule is a possible sequela to abdominal trauma or hematoma, and many affected ferrets require a blood transfusion (Fig. 29). Two primary surgical techniques are used for splenic surgery: partial splenectomy and total splenectomy. Total splenectomy is the most common, an easier procedure to perform, whereas partial splenectomy is rarely indicated. The surgical procedure in ferrets is identical to that performed in dogs and cats.[22] A vascular sealing instrument, such as a LigaSure device, is useful and contributes to a reduction in the surgical time. Because the spleen is a major site of erythropoiesis in ferrets, the consequences associated with a total splenectomy to a patient should be carefully considered prior to undertaking the surgery.[22]
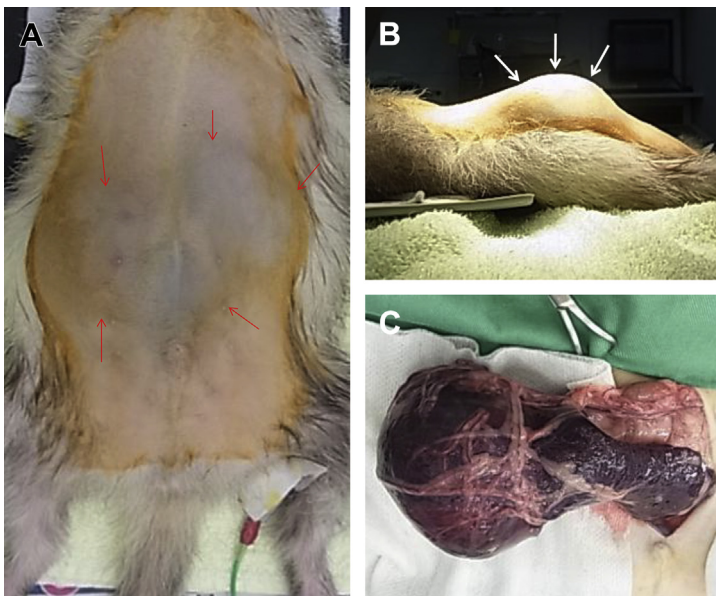

Fig. 28. Splenomegaly is common in ferrets and typically represents extramedullary hematopoiesis, which is not surgical. (A, B) Appearance of the enlarged spleen (arrows) and (C) intraoperative splenomegaly. Surgery for enlarged spleen may be indicated when there is interference with abdominal visceral function.
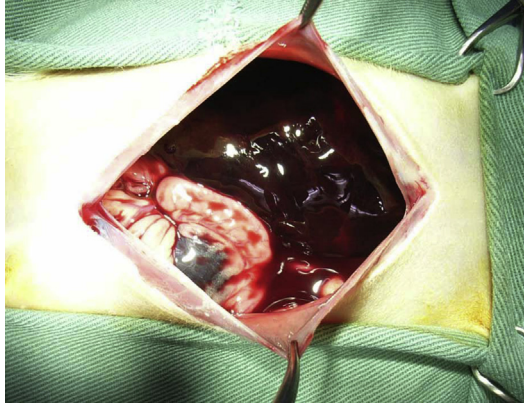
Fig. 29. Laceration of the splenic capsule due to trauma in a ferret. An enlarged ferret spleen may be ruptured by falling or other trauma. In these cases, blood transfusion is commonly recommended.

Urinary Tract Surgery

Urolithiasis

Urolithiasis is a disease manifestation in which a single urinary calculus or multiple calculi are found anywhere in the urinary system. Urolithiasis is common in Guinea pigs and chinchillas but less common in ferrets and other rodent species. Most cases in Guinea pigs and chinchillas were cystoliths and a few renoliths. The overall prevalence of uroliths in ferrets has decreased during the past 10 years due to higher-quality diets, although the authors have observed a recent spike in the incidence of cysteine uroliths, which has been anecdotally attributed to feeding a commercial grain-free diet.[24,25] Prior to the recent increase in cysteine uroliths in ferrets, the most common urinary calculus was magnesium ammonium phosphate (struvite), and inappropriate diets causing alkaline urine were linked to the disease.[25] In one author's (YM) experience, dietary management and subsequent reduction of urine pH contributed to resolution of struvite calculi in the urinary bladder of a ferret after converting the diet to a commercial ferret kibble from a vegetable-based diet (Fig. 30). In Guinea pigs, calcium
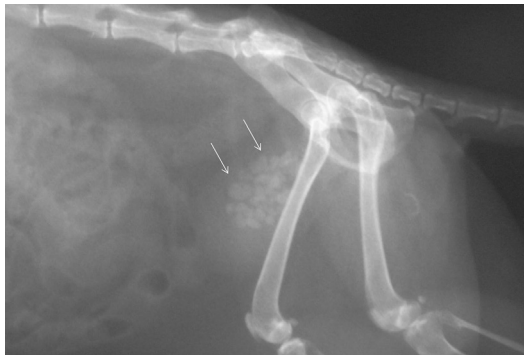

Fig. 30. Lateral radiograph of a ferret, which was fed only vegetables for several years. Many struvite calculi (*arrows*) were observed in the urinary bladder. These calculi were completely dissolved by converting to a proper ferret diet.

is the major constituent of urinary calculi. In all small mammals, the most common clinical signs include hematuria, stranguria, dysuria, anorexia, hunched posture, and vocalization during straining to urinate. Diagnosis is based on imaging via radiographs, CT, or ultrasound. It is important to include the entire urinary system, including the distal penis, when taking radiographs. In male Guinea pigs, ultrasound is beneficial to evaluate the location of calculi, because some calculi are rarely located in the seminal vesicles (Fig. 31). Because the urinary pH of herbivorous small mammals is normally alkaline, the use of the urinary acidifiers is contraindicated, and prevention or medical treatment is unrewarding.[26] Therefore, surgical removal of uroliths is the treatment of choice in herbivorous small mammals.

A cystotomy procedure in small mammals is the same technique used in dogs and cats. A ventral midline incision is performed through the skin and muscle layers and the urinary bladder exposed. Two stay sutures are placed on each side of the urinary bladder and sterile, saline-soaked gauze sponges are used to pack around the bladder to maintain tissue moisture and prevent urine contamination back into the patient's abdomen. It is useful to insert a small gauge hypodermic needle into the bladder to empty it of urine prior to making the incision. The urinary bladder is incised approximately along the ventral midline from cranial to caudal and the uroliths removed. Some uroliths are adhered to the urinary bladder mucosa, and care must be taken to peel them from the bladder wall, because hemorrhage is common. To ensure patency of the urethra, a red rubber tube can be passed from the bladder through the urethra and exteriorized. Any remaining small calculi can be flushed using sterile saline. The urinary bladder is closed in 2 inverting layers (eg, Cushing-Connell) using 3-0 to 5-0 monofilament, absorbable suture material. The body wall can be closed using 3-0 or 4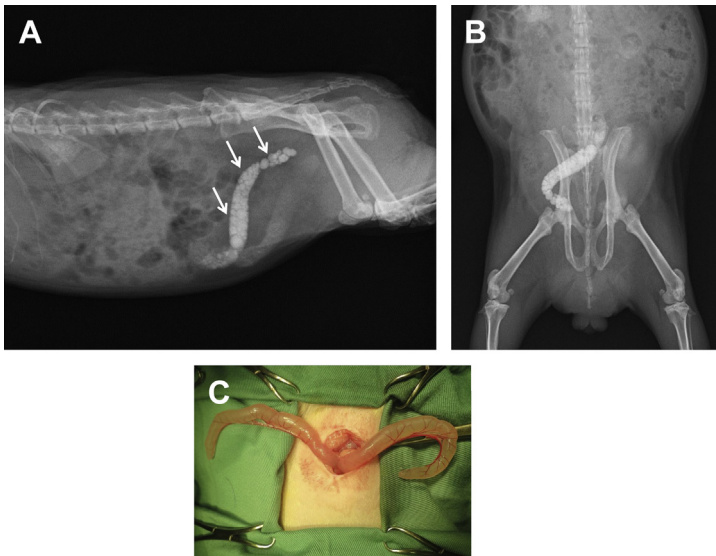-0 monofilament, absorbable suture material in a simple continuous pattern and the skin can be closed using 3-0 or 4-0 monofilament, absorbable suture material

Fig. 31. Calculi locate in the seminal vesicles in a male guinea pig. (A) Lateral radiograph (B) and ventrodorosal radiograph. (C) Normal intraoperative appearance of Guinea pig seminal vesicles. Ultrasound is necessary to evaluate the location of calculi (arrows) in male guinea pigs because some calculi are located in the seminal vesicles rather than the urinary tract.

in a subcuticular, continuous suture pattern or simple interrupted skin suture. Skin staples can also be used and may help prevent the patient chewing through skin sutures. After the surgical removal, it is important to submit the calculi for chemical analysis so that preventative dietary changes can be implemented.

Urethral calculi are more common in males than females of most small mammal species, and many urethral stones can be palpated during the physical examination. Confirm the location of the urethral stone by palpation and imaging. Once the location is identified, incise over the stone, dissect the skin and subcutaneous tissue, and identify the urethral wall. Incise the urethral wall and remove the stone, and be careful removing if the urolith is adhered to the urethral mucosa (Fig. 32). To close the urethra, suture the urethral wall in 1 layer using 5-0 or 6-0 monofilament, absorbable suture material in a simple continuous pattern, then close the skin using a subcuticular or simple interrupted skin closure. In some cases in which a urethral stone cannot be palpated, a urethral catheter and an attached syringe filled with sterile saline can be used to retropulse the stone into the urinary bladder for removal via cystotomy.

Ureteral calcului are rare in small mammals but frequently cause complete ureteral obstruction and require prompt surgical removal. Clinical signs may vary, depending on whether or not the stone has caused a complete obstruction. Unilateral ureteral calculi with complete obstruction result in hydronephrosis and hydroureter and may present without subsequent renal failure, but bilateral, obstructive ureteral calculi contribute to renal failure. Imaging modalities can help with diagnosing ureteroliths, hydroureter, and hydronephrosis. The authors have experienced bilateral ureterolithiasis in Guinea pigs (Fig. 33), which can be resolved with prompt surgical removal of stones and intensive supportive care. The surgical procedure is similar to that performed in dogs and cats, but the monofilament, absorbable suture material needs to be small depending on the species: 5-0 to 8-0. Renal calculi or renal mineralization is occasionally diagnosed radiographically, concurrent with ureteral stones. Whether all renal or ureteral stones should be removed is controversial, and recurrence is expected.

Reproductive Tract Surgery

Reproductive tract surgery in rodents, ferrets, and hedgehogs can be an elective procedure for removal of ovaries and uterus, or testicles, to prevent pregnancy and future diseases associated with reproductively intact animals (eg, uterine and mammary neoplasia, ovarian cysts, and testicular neoplasia).[7,9] In some cases, early testicular and ovarian removal may alter certain gender-specific behaviors. Alternatively,
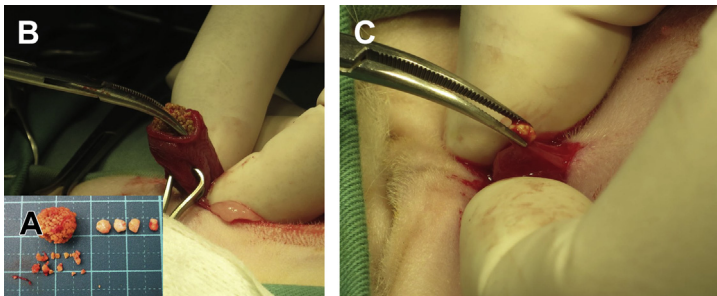

Fig. 32. Surgical removal of urinary bladder and urethral calculi in a ferret. (A) Cystine calculi were removed from (B) bladder and (C) urethra. The surgical procedure is similar to that in dogs and cats.
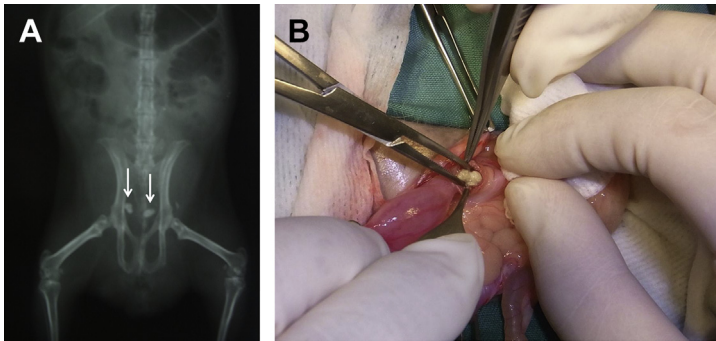
Fig. 33. Bilateral ureteral calculi in a guinea pig. (*A*) Radiograph of the abdomen; (*B*) intra-operative image. Results of the radiograph demonstrates 2 ureteral calculi (*arrows*). The ureteral calculi, located in both ureters, were surgically removed and analyzed to reveal composition of calcium carbonate.

reproductive surgery may be therapeutic in cases of reproductive tract diseases. Most ferrets in North America and Japan are routinely spayed or neutered and undergo simultaneous anal sacculectomies at a young age. Therefore, it is uncommon for clinicians to perform such procedures in many countries. This is not true in European countries, however, in which elective ferret orchiectomy and ovariohysterectomy are more common.

Elective Orchiectomy and Ovariectomy or Ovariohysterectomy

Orchiectomy
Although the surgical techniques associated with orchiectomy in small mammals is not significantly different from techniques used in dogs and cats, there are a few differences worth highlighting. In most rodent species, especially Guinea pigs and chinchillas, the inguinal canal is large diameter, and the testicles move freely from the abdominal cavity into the scrotum.[7] This open inguinal canal is important with respect to the chosen procedure for orchiectomy. There are 2 primary surgical approaches to castrating rodents: bilateral scrotal incisions, with open or closed castration, or a single, prescrotal incision, in which both testicles are excised from the same incision with either an open or closed procedure.[7] The prescrotal approach can be more efficient with 1 less incision, but care must be taken with hedgehogs, chinchillas, and Guinea pigs because the penis is comparatively large and frequently directly in the surgical field. Although many clinicians profess one procedure better than the other, the authors have performed many open and closed orchiectomies through 1 or 2 incisions and have not observed significant complications from any of the chosen surgical procedures. Once the patient is anesthetized and surgically prepared, bupivacaine (2 mg/kg) or lidocaine (4 mg/kg) with 50% of the total dose administered directly into each testicle as a local nerve block (**Fig. 34**). Either bilateral cranial scrotal (**Fig. 35**) or single, prescrotal incisions are made. The general procedure is similar as that used in dogs. Whether using an open or closed technique, it is important to leave as much nontesticular tissue in the distal inguinal canal (eg, the vaginal tunic and epididymal fat pad) to prevent herniation of abdominal organs into the inguinal canal. Application of Hemoclips for ligating vessels can decrease surgical time compared with tying ligatures. Once the testicles are removed, it may be beneficial to use a sterile cotton-tipped applicator to place remaining tissues back into the inguinal canal. In

Fig. 34. Intratesticular administration of a local anesthetic, bupivacaine (2 mg/kg) or lidocaine (4 mg/kg), with 50% of the total dose administered directly into each testicle, as a local analgesic. This technique can be used in all male small mammals.

cases in which the tissues are difficult to push cranially into the inguinal canal, it may be helpful for an assistant to hold the tissues within the canal and place a deep subcutaneous suture line to close the canal and prevent further herniation into the scrotum. Minimize quantity of suture material in Guinea pigs, however, due to potential for inflammation and abscessation. The prescrotal or scrotal skin incisions can be closed using a subcuticular pattern (3–0 or 4–0 absorbable, monofilament suture material), nonabsorbable skin sutures or skin staples.

In male sugar gliders, the testicles are located in a pendulous scrotum that is suspended from the ventral midline, midway between the sternum and pubis. The most effective and efficient surgical approach, with the least likelihood for postsurgical self-mutilation by the patient, is by use of a CO_2 laser (**Fig. 36**).[27] The scrotal stalk is shaved and aseptically prepared and bupivacaine (2 mg/kg) or lidocaine (4 mg/kg)
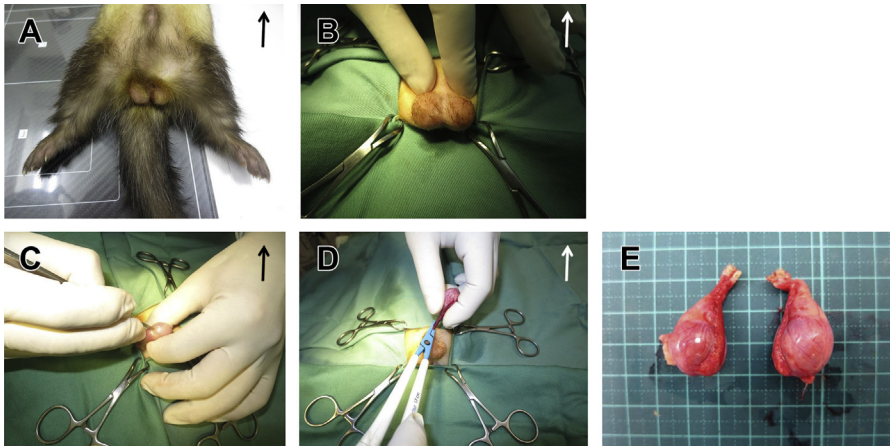

Fig. 35. Male ferret undergoing castration surgery using bilateral scrotal incisions and a closed technique. (*A*) Appearance of perineal region of an intact male ferret. (*B*) Presurgical preparation of male ferret scrotum. (*C*) Skin incision of scrotum to expose the testicle. (*D*) Spermatic cord ligated; E: Surgically removed testicles of male ferret. *Arrows* indicate craniad.
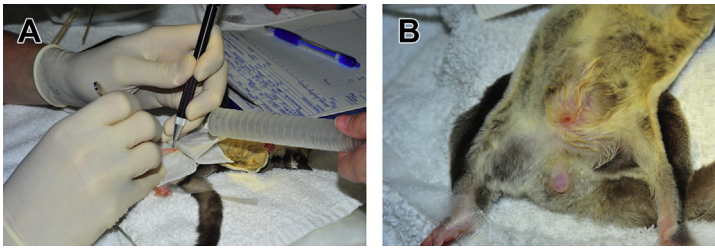
Fig. 36. Male sugar glider undergoing a castration procedure using a CO_2 laser technique. (A) Application of CO_2 laser cutting the scotal stalk skin and spermatic cords in a single motion. (*B*) Immediate post-operative image of small surgical wound. (*Courtesy of* C. Mans, DVM, DACZM, Madison, WI, USA.)

with 50% of the total dose administered directly into each testicle. Frequently, the size of the testicle limits the volume of local anesthetic instilled in each testicle; for example, it is difficult to administer much more than 0.2 mL in a typical rat testicle or 0.05 mL in a sugar glider testicle. A tongue depressor is placed between the glider's body and the scrotal stalk, and the laser is applied to the stalk cutting rapidly in transverse section, close to the body wall, so as not to leave excess tissue. The laser cuts and cauterizes instantly (see **Fig. 36**). One consequence of using the CO_2 laser is that the skin of the sugar glider skin appears to puff up during laser application, and this can be alarming to a first time user. Also, be careful with a cavalier approach to laser application, because significant, collateral tissue damage may be a consequence. In the authors' experience, there is no postsurgical self-mutilation of the surgical site after use of the laser, whereas self-mutilation is common if using a traditional, scalpel-based surgical approach with sutures.

Ovariectomy/Ovariohysterectomy

As discussed previously, elective ovariectomy and ovariohysterectomy surgical procedures used in small mammals are similar to those used in dogs and cats, with a few notable exceptions. A flank approach to ovariectomies in rodents is, currently, more commonly used than 5 years ago.[7] Laparoscopic ovariectomies are commonly performed in academic veterinary hospitals on dogs and cats, but this approach is not used routinely in small mammals. Other differences include varies and uteri are smaller and tend to be more friable in small mammals, especially rodents, compared with dog and cat tissues. Two surgical approaches are used for ovariectomies and ovariohyterectomies in rodents, ferrets, and hedgehogs.[7] Elective ovariectomy or ovariohysterectomy of sugar gliders is uncommon due to the significant likelihood of postsurgical self-mutilation. The traditional, ventral midline approach to ovariectomy/ovariohysterectomy is identical to the same approach in dogs and cats, although tissues in small mammals are smaller and more friable. In addition, female Guinea pigs have less elastic ovarian suspensory ligaments, which makes ovarian visualization and exposure much more difficult. Application of Hemoclips or use of a LigaSure device can be useful for ligating vessels and hemostasis, because suture ligatures are time consuming and may be difficult in species in which the ovaries are not easily exposed. The uterus can be clamped and ligated at the level of the cervix in most species. The alternative surgical approach for elective ovariectomy is through flank incisions.[7] The primary advantages of this approach include, a shorter procedure, less visceral organ manipulation, faster recovery time, and less postsurgical pain. It is easiest to make 2

flank incisions, 1 in each flank region. The primary disadvantage is lack of access to the uterus, which is most problematic if the surgical procedure is conducted because of pathology. The skin incisions are made, one at a time, in the paralumbar region, from the last rib to the lateral processes of the lumbar vertebrae. The muscle layer is incised and the tissues bluntly dissected. Bipolar cautery can be used for hemostasis. The ovary can be gently manipulated and exposed and a hemostat placed across the ovarian vessels. Hemoclips or suture ligatures can be applied to the ovarian pedicle and the ovary excised. A standard, 2-layer closure of the muscle layer and skin can be performed using suture material and/or staples for the skin layer. The opposite ovary is approached in the same manner.

For nonelective reproductive tract procedures, the primary reproductive diseases associated with ferrets, rodents, and hedgehogs includes Guinea pig ovarian cysts and caesarian sections, pyometra, or mucometra in various species. Ovarian cysts are commonly observed in female Guinea pigs and frequently require surgical intervention.[27–30] Typical clinical signs include bilaterally symmetric and nonpruritic alopecia and abdominal distention associated with enlarging ovarian cysts (**Fig. 37**). Diagnosis is suspected based on typical clinical signs and palpation and confirmed using abdominal ultrasonography or CT. As discussed previously, normal ovaries of guinea pigs have short ovarian ligaments and tend to be located in a more dorsal position compared with rabbits, which can make access to the ovaries more difficult when a ventral midline incision is used. Therefore, some surgeons prefer a dorsal flank approach to the Guinea pigs ovaries.[7] On the other hand, the ovarian cysts are frequently large and easily manipulated through a ventral midline incision, and both authors typically use this approach for ovarian cysts (**Fig. 38**). Once the incision is made, be careful with excessive manipulation of other abdominal organs, especially the gastrointestinal organs, because Guinea pigs tend to have a more dramatic inflammatory reaction to organ manipulation that other small mammal species. It is best to protect the other abdominal organs with moist gauze and minimize traction of the uterus and ovaries. In cases in which the ovarian ligaments are flaccid and stretched by the enlarged ovaries, providing good access to the ovarian pedicle, monofilament, absorbable suture material can be used to place ligatures (**Fig. 39**), or a LigaSure device can be used to ligate the ovarian vessels. For those cases in which the ovarian ligaments are not elastic and extraction of ovaries is difficult, Hemoclips can be useful for ligating the ovarian vessels. A bilateral ovariohysterectomy is most commonly used by the authors, but when only 1 ovary is cystic and approaching

Fig. 37. Female guinea pig with typical clinical signs associated with ovarian cysts. These include bilaterally symmetric and nonpruritic alopecia and abdominal distention.
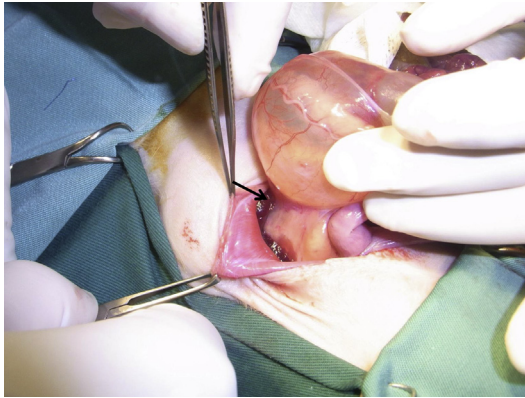
Fig. 38. Ovarian cyst with the ovarian ligament of a female guinea pig. Ovarian ligaments (*black arrow*) of guinea pigs are shorter and less elastic than ovarian ligaments of most other small mammals.

the other side via a ventral midline incision is difficult, a unilateral ovariectomy may be elected.

For uterine or vaginal lesions, including neoplastic diseases and pyometra, the appropriate reproductive organs are surgically removed using a ventral midline approach. With uterine or vaginal pathologic lesions, an ovariohysterectomy is most commonly performed. Because the ovaries of Guinea pigs can be difficult to access through a midline incision, discussed previously, one of the authors (YM) surgically removes uterine or vaginal lesions and leaves the ovaries intact if there is no concurrent ovarian pathology. Large vaginal masses are sometimes observed in female Guinea pigs and may appear unresectable based on ultrasound or exploratory laparotomy results. From the authors' experiences, however, these masses are easy to remove due to minimal adhesions, despite the size of the mass. In such cases, a ventral midline approach is used and the ovaries and uterus are surgically removed. The vagina is incised, the mass is peeled away from the mucosa, and bipolar cautery
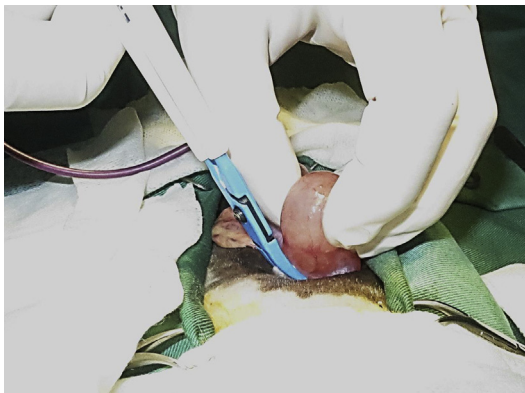

Fig. 39. When the ovarian ligaments are flaccid and stretched enough by the enlargement of the ovaries, use vessel sealing system, such as LigaSure or absorbable suture, for ligation.

is used for hemostasis. The vagina can be closed using 3-0 to 4-0 monofilament, absorbable suture in a 2-layer inverting pattern, and the muscle layer and skin closed as previously described.

Intact female Guinea pigs allowed access to males become pregnant and commonly experience dystocia, which requires caesarian section.[7,9] If female Guinea pigs experience their first parturition prior to 8 months of age, there is dehiscence of the tuberculum pubicum and parturition is smooth. Without an early parturition, however, female Guinea pigs develop a very small pubic opening, leading to dystocia. With pregnancy, the pubic symphysis of all females should be examined radiographically and a caesarian section performed when necessary. The procedure is identical to that of a dog or cat, using a ventral midline approach (**Fig. 40**). The uterus incision should be closed in 2 inverting layers.

In hedgehogs, neoplastic diseases are common, and mammary gland tumors tend to have the highest published incidence.[31] Based on the authors' experience, however, the most common reproductive organ affected by neoplasia is the uterus. Uterine masses are commonly diagnosed in middle-aged and older (greater than 2 years) hedgehogs and present with hematuria, and hemorrhagic discharge from vulva (**Fig. 41**). With sedation or anesthesia, uterine masses are usually palpable in the caudal abdomen and can be confirmed using CT or ultrasonography. Ovariohysterectomy is usually curative if the tumor is contained within the uterus. The hedgehog is placed in dorsal recumbency, and an approximate 2-cm midline incision is made from the umbilicus caudally. The swollen, discolored uterus is detected and is lifted through the incision with Babcock forceps (**Fig. 42**). The uterine horns are coiled and broad ligament of the uterus is narrower and tighter than in rabbits, for example (see **Fig. 42**). Some ovarian and mesometrial vessels are visible, but they tend to be small and hemorrhage is seldom a problem if using Hemoclips or a LigaSure device. In some of these cases, however, there can be excessive hemorrhage, and perioperative or postoperative death is possible due to blood loss. The uterus can be transfixed using 3-0 or 4-0 monofilament, absorbable suture material, and transected at the cervix or vagina. The muscle layer is closed using 4-0 monofilament, absorbable suture material in a simple continuous patter, and a subcuticular pattern can be used to close the skin or skin sutures or staples used.

Additional Ferret Surgical Procedures

The prevalence of neoplastic diseases in ferrets has changed over the past several decades with respect to primary organ system involved. Reproductive system neoplastic diseases were most common in the 1970s and 1980s or second only to
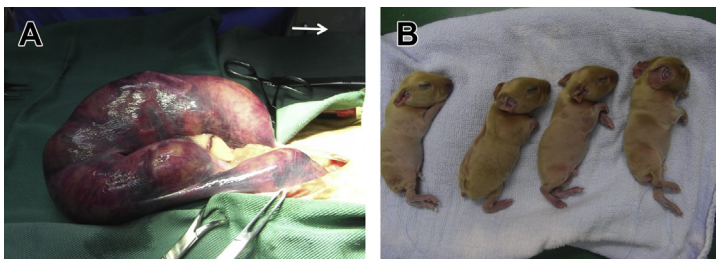

Fig. 40. Caesarian section in a female guinea pig. (*A*) Intraoperative appearance of the pregnant uterus. (*B*) New-born infants delivered by Caesarian section. *Arrow* indicates craniad.
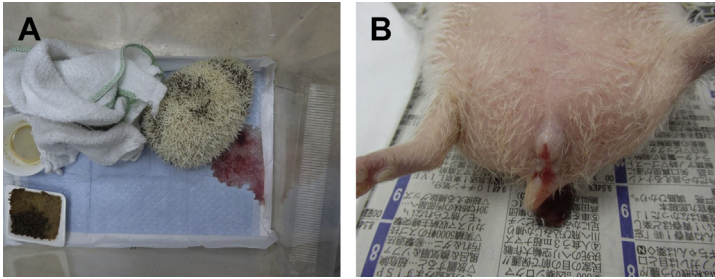
Fig. 41. Hematuria (*A*) and/or vulvar hemorrhage (*B*) in a female hedgehog with reproductive disease.

lymphoma.[32–34] The prevalence of reproductive system tumors has significantly decreased, however, whereas the prevalence of endocrine neoplasia, including adrenal adenoma/adenocarcinoma and pancreatic beta cell tumors (ie, insulinoma), has increased.[35–39] This changing prevalence of neoplastic diseases in ferrets can be attributed to the fact that most pet ferrets sold in North America and Japan are neutered and descented at an early age. Both authors have performed multiple ovariohysterectomies and anal sacculectomies on retired breeding ferrets (**Fig. 43**). The ovariohysterectomy procedure in a ferret is identical to that in a small cat. Both authors have experienced cases in which stump pyometra is diagnosed, and surgical excision of the distended uterine stump was completed. Castration of male ferrets is similar to the procedure used in a small dog (see **Fig. 35**).
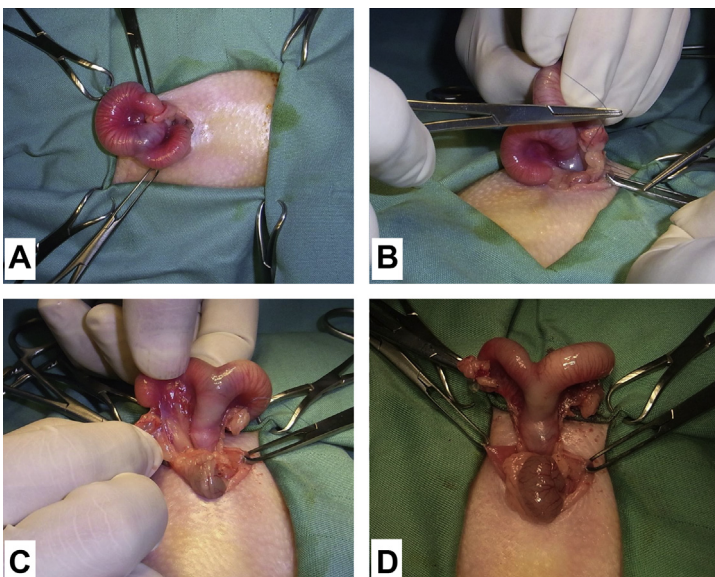

Fig. 42. Female hedgehog undergoing an ovariohysterectomy of diseased uterus. Female hedgehog uterine horns are coiled and the broad ligament of the uterus is narrower and tighter compared with the reproductive tract of other female small mammals. (*A*) Uterine horns exposed peri-operatively in a female hedgehog. (*B*) Ligature transfixation of uterine body of female hedgehog. (*C, D*) Excision of uterus and ovaries from the female hedgehog.
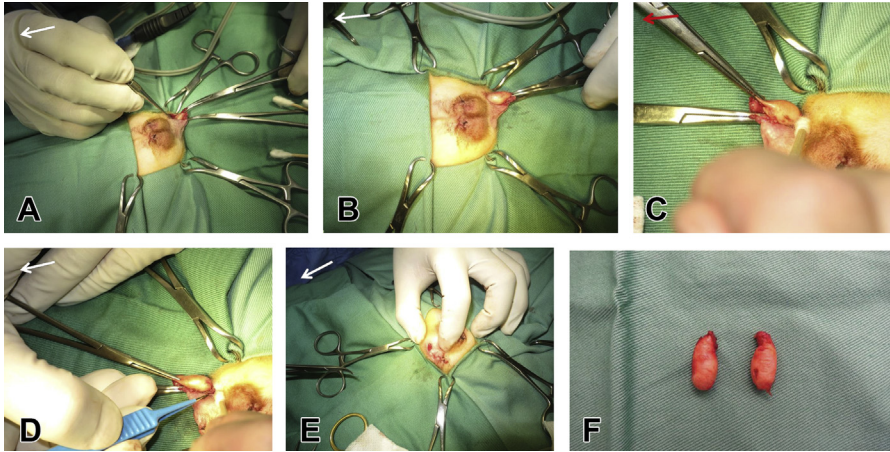
Fig. 43. Anal sacculectomy of a ferret. The perianal gland ducts are identified and os of the gland is clamped using a small hemostat (*A*). A circumferential incision is made (*B*) closely associated with the duct and the gland is slowly and carefully, bluntly dissected from the surrounding muscle (*C*). A scalpel blade and bipolar cautery are used to scrape the muscle from the serosal surface of each gland, being careful not to rupture the gland (*D*). Both glands are excised and the surgical wounds left open to heal by second intention (*E*). Excised anal glands are shown (*F*). *Arrows* indicates craniad.

Although uncommon, mammary gland neoplasia is observed in ferrets and is most commonly associated with concurrent adrenal disease and increased reproductive hormones. In cases of mild enlargement of mammary gland or enlargement of the nipples only (Fig. 44), these symptoms may resolves with surgical removal of the diseased adrenal gland or medical management by using deslorelin implants. On the other hand, in cases in which a solid mammary tumor is observed, the diseased mammary tissue should be surgically excised (see Fig. 44).

Endocrine Surgery

Adrenal adenoma/adenocarcinoma and pancreatic beta cell tumors are the 2 most common endocrine diseases in domestic ferrets, and both diseases can be managed either medically or surgically. The surgical techniques for adrenalectomy and excision of pancreatic beta cell tumors in ferrets are described.

Adrenalectomy

Many cases of adrenal adenoma/adenocarcinoma in ferrets are now managed using deslorelin implants to control the clinical signs. This medical management does not affect the disease progression, only the signs associated with increased androgens and estrogens. Surgical removal of the adrenal gland is an option, and can provide increased time to recurrence. Typical clinical signs associated with adrenal disease in ferrets include alopecia, pruritus, skin excoriations, lethargy, swollen vulva in females, stranguria in males due to prostatic enlargement and urethral compression, and thin skin. Diagnosis is based on endocrine panels and/or ultrasonographic evidence of an enlarged or misshapen adrenal gland or glands. The adrenal glands are located near the craniomedial pole of the kidneys and surrounded by large amount of fat within the retroperitoneal cavity. The right adrenal, like the kidney, is located more cranially and closely associated with the dorsomedial aspect of the caudal
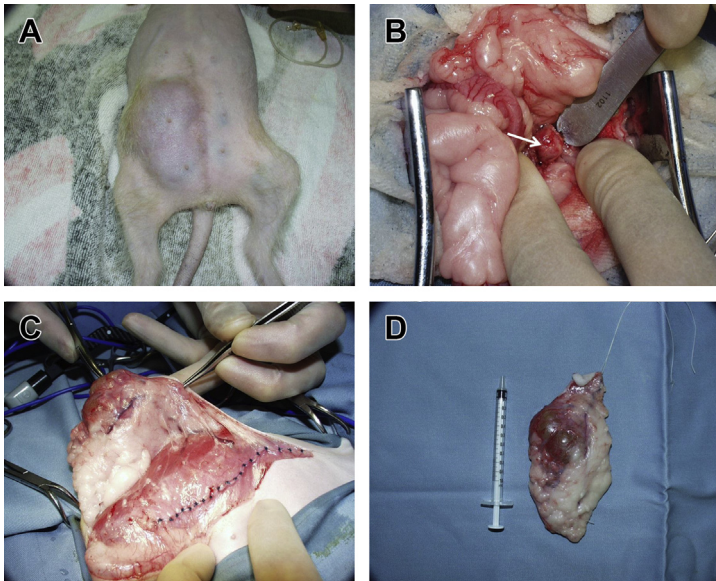
Fig. 44. Female ferret with mammary duct ectasia accompanied by adrenocortical carcinoma. (*A*) Appearance of the lesion (*B*) Note the enlarged left side adrenal gland (adenocortical carcinoma) (*arrow*). (*C*) Enlarged mammary gland was surgically resected. (*D*) The affected mammary gland was diagnosed as mammary duct ectasia.

vena cava. Therefore, surgical removal of the right adrenal gland is technically more challenging than surgical removal of the left adrenal gland. The surgical approach to the abdomen is routinely performed via a ventral midline approach and the retraction of the spleen and intestines from the surgical field to visualize the adrenal glands. Although both adrenals are located within the retroperitoneal fat (**Fig. 45**), the affected adrenal gland(s) is enlarged, irregularly shaped, discolored, and readily visible (**Fig. 46**). Although 1 gland may have an abnormal appearance on ultrasound images, both adrenal glands may be affected, and a subtotal, bilateral adrenalectomy is warranted. The authors usually attempt to remove the affected adrenal gland and debulk the other, leaving some of the capsule behind. The authors have not observed any
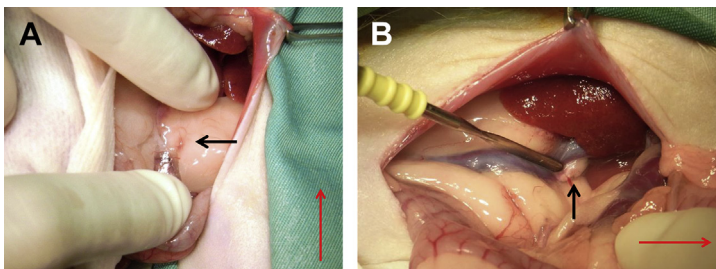

Fig. 45. Appearance of the normal ferret adrenal gland (*A*) left adrenal and (*B*) right adrenal. *Red arrow* indicates cranial. The adrenal glands (*black arrows*) are located within the retroperitoneal cavity and surrounded by a large amount of fat. (*B*) The right adrenal is located under the caudate liver lobe and adhered to the caudal vena cava.
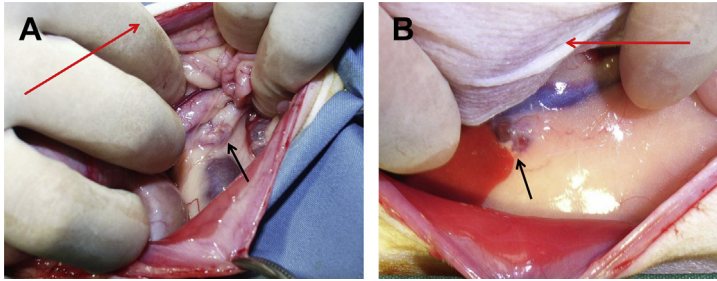
Fig. 46. Appearance of an abnormal ferret adrenal gland: (*A*) left adrenal and (*B*) right adrenal. Red arrow indicates cranial. Although both adrenals (*black arrows*) are located within the retroperitoneal fat, most of the affected adrenal is irregularly shaped, discolored, and readily visible.

ferret developing long-term hypoadrenocorticism crisis postbilateral adrenalectomy, but immediate postsurgical treatment with corticosteroids may be beneficial.[39] Accessory adrenal glands are occasionally observed and these tissues may compensate after the bilateral adrenalectomy in ferrets. The procedures associated with left adrenectomy (**Fig. 47**) and right adrenalectomy (**Fig. 48**) in ferrets are shown. Use of a CO_2 laser (**Fig. 49**) and cryosurgical probes has been described for right-sided
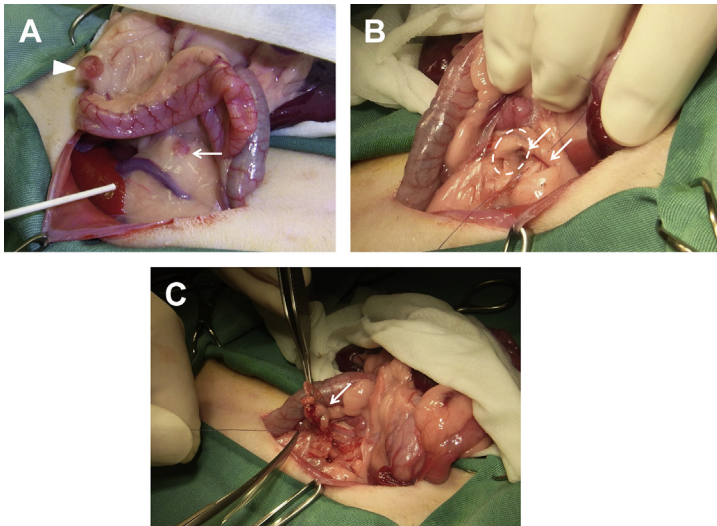

Fig. 47. Left adrenalectomy in a ferret. (*A*) The spleen and small intestines are retracted toward the right side in the body or exteriorized through the incision line. Confirm the left adrenal gland (*arrow*), which is located cranial to the cranial pole of the left kidney. A swollen lymph node (*arrowhead*) was observed, and the final diagnosis in this case was lymphoma. (*B*) Confirm the adrenolumbar vein (*arrows*), which runs from lateral to medial over the ventral surface of the left adrenal (*dotted line*), and ligate this vessel at the distal aspect using 4-0 absorbable suture or Hemoclips. (*C*) Separate the affected adrenal gland completely from the surrounding tissue, ligate the proximal part of the adrenolumber vein, and remove the affected gland (*arrow*).
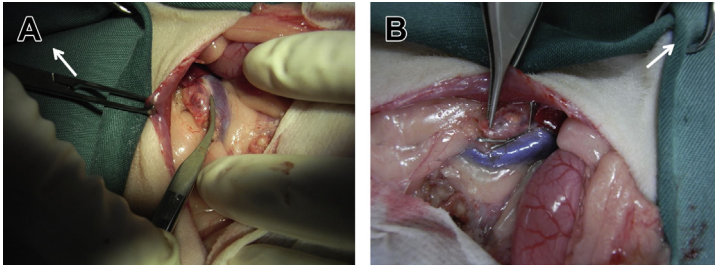
Fig. 48. Right adrenalectomy in a ferret. (*A*) Retract the spleen and intestines toward the left side in the body or exteriorize through the ventral midline incision. Confirm the right adrenal gland, which is located cranial to the cranial pole of the right kidney. The right adrenal gland is usually directly adhered to the vena cava and care must be taken to not lacerate this vessel during the procedure. (*B*) Hemoclips are useful for hemostatsis and ligation of vessels. Continue the same procedure as the left adrenalectomy, and detach the adrenal from the vena cava. *Arrow* indicates craniad.

adrenalectomy. A complete abdominal exploratory is important to evaluate the abdominal organs, especially to check the pancreas for nodules.

Insulinoma

Surgical treatment of insulinoma in ferrets

Insulinomas are functional tumors of the beta cells of the islands of Langerhans, which secrete insulin despite the presence of hypoglycemia, and insulinoma is the most common neoplastic diseases of ferrets.[39] A tentative diagnosis of insulinoma is based on clinical signs associated with hypoglycemia and confirmation of the low blood glucose concentration lower than 60 mg/dL.[39] Because most pancreatic beta cell tumors are not discrete nodules and, therefore, difficult to diagnose using imaging modalities, medical management is frequently the treatment of choice. Medical management includes corticosteroids, such as prednisolone or prednisone, administered orally. Treatment may alleviate clinical signs associated with hypoglycemia but does not alter the progression of the disease process. Surgical excision of discrete pancreatic nodules is the recommended treatment of insulinoma in ferrets (**Fig. 50**).
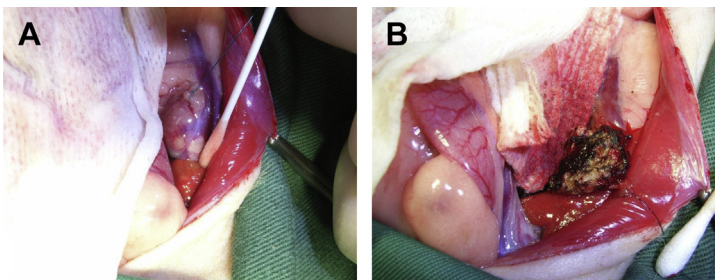

Fig. 49. Right side partial adrenalectomy in a ferret using a CO_2 laser. The affected adrenal infiltrated into caudal vena cava, and the owner denied aggressive surgery. After partial resection of the affected adrenal for histopathological evaluation, residual tissues were vaporized by CO_2 laser. (*A*) Appearance of the affected adrenal. (*B*) Appearance of the dorsal aspect of the adrenal gland after CO_2 laser vaporization.
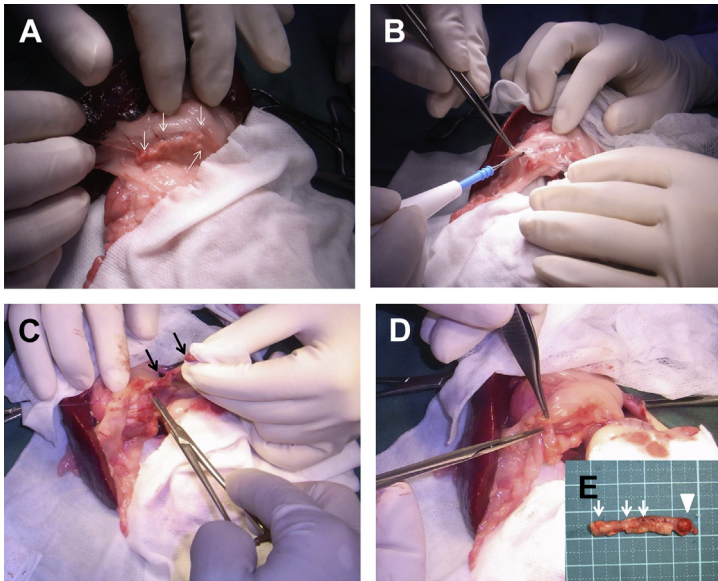
Fig. 50. Partial pancreatectomy as a surgical treatment of insulinoma in a ferret. (*A*) Multiple nodules (*arrows*) are confirmed in the left pancreatic lobe. (*B*) Incision of surrounding tissue associated with the affected pancreas lesion. Surgically removing any tumor nodules with a wide margin is important. (*C*) Isolate the affected nodule (*arrow*) and place a loop of suture around the lesion. Tighten the suture and allow it to crush through the pancreatic parenchyma. (*D*) Excise the specimen, distal to the ligature. (*E*) In the excised pancreas, there is 1 large nodule (*arrowhead*) and multiple small nodules (*arrows*).

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