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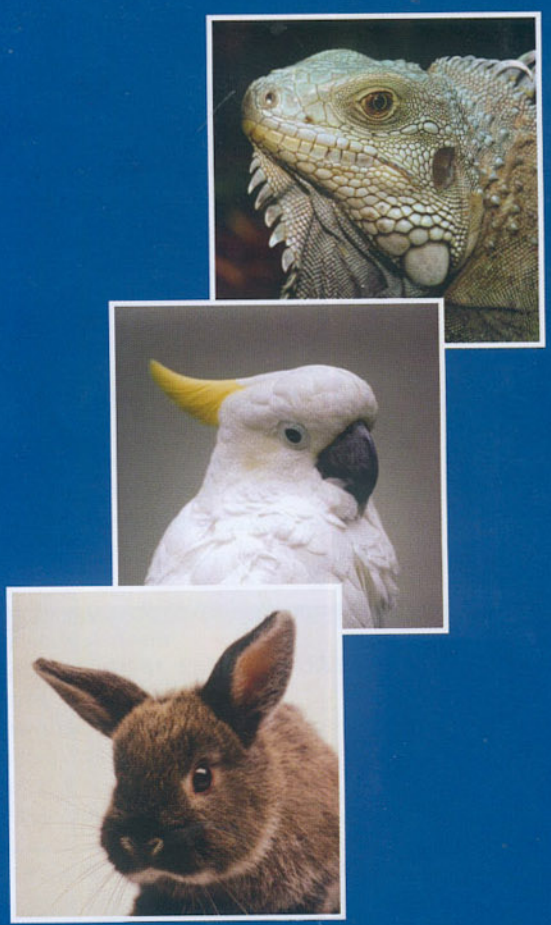

This Issue:
Clinical Rodent Medicine

Javier Nevarez, DVM, PhD
Guest Editor

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Common Surgical Procedures in Pet Rodents

Vittorio Capello, DVM, Dip. ECZM (Small Mammals), Dip. ABVP (Exotic Companion Mammal)

Abstract

Performing surgical procedures, whether elective or therapeutic, on pet rodents is an important component of clinical exotic companion mammal medicine. The most common surgical procedures involve the reproductive system (both elective and therapeutic) and the integument. Dental procedures are also frequently performed on pet rodents and knowledge of normal, topographic and surgical anatomy is essential to adequately perform routine as well as complex surgical procedures on these companion animals, as well as specialized equipment. This article reviews the basic principles of surgery and common surgical procedures. Copyright 2011 Published by Elsevier Inc.

Key words: **orchiectomy; ovariectomy; ovariohysterectomy; rodents; surgery**

Performing surgical procedures on companion rodent patients has become routine, since pet owners have increased their demand for quality veterinary care. In recent years there has been a rise in the number of scientific case reports with a focus on rodent surgery because of the advancement of veterinary skills, availability of specialized instruments and supplies, progress in anesthesia and analgesia, and qualified professional preoperative and postoperative nursing. Medicine and surgery of companion rodent species are even acknowledged as a specialty of Zoological Medicine within the European College of Zoological Medicine (ECZM–Small Mammals) and the American Board of Veterinary Practitioners (ABVP–Exotic Companion Mammals).

Among mammals, the order *Rodentia* is the largest, with over 1700 species. Although most rodent species are nondomestic, many are maintained as pets in either zoological institutions and/or private collections. The knowledge of individual rodent species behavior, anatomy, and physiology is critical when assessing a patient for a potential surgical procedure and when performing the actual surgery, especially when considering the application of surgical techniques. When very large, nondomestic rodents (e.g., capybara, beavers, porcupine) are excluded, 3 groups of rodents are commonly encountered as companion species: the "large" rodents (e.g., guinea pig, Patagonian cavy, prairie dog, and large squirrels) with an average adult weight of 1 kg or higher; intermediate-sized rodents (e.g., chinchilla, rat, degu); and small rodents (e.g., hamsters, gerbils, mice, chipmunk, and small squirrels) weighing on average 100 g or less.

Every single parameter pertaining to surgery (e.g., diagnostic imaging, anesthesia and monitoring equipment, surgical skills, prognosis, postoperative care) is greatly influenced by the size of the patient, and may be significantly different for those three groups.

Anesthesia and Analgesia

Extensive review of sedation, anesthesia, monitoring, and analgesia is beyond the scope of this article; however, this information can be found elsewhere.[1-4] Although many different rodent analgesia/anesthesia

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protocols have been reported, the same general principles used for the analgesia/anesthesia in canine and feline species can be applied to rodents. There are however some critical considerations when working with rodents. The large surface:volume ratio of small mammals predisposes these animals to hypothermia. It is imperative that rodent patients are provided extracorporeal heat and their body temperature monitored during all phases of their anesthesia and surgical procedure. Failing to monitor the patient's body temperature may lead to the death of the animal. Whenever possible, vascular or intraosseous catheters should be used for administration of supportive fluids.[5] Finally, airway access can be very challenging in rodent patients. Endoscopic-guided techniques for endotracheal intubation are described in the literature.[6,7] Although endotracheal intubation is ideal, the availability of this equipment, skill level to use this equipment by the veterinarian, and risk:benefit ratio must be assessed for each patient if this procedure is to be successfully accomplished.

Equipment

It is generally accepted by the veterinary community that surgical procedures of pet rodents are "microsurgery." This is not completely true, because most surgical procedures, especially in larger rodents, can be performed with readily available surgical instruments and the surgeon having intermediate surgical skills. Nevertheless, some specialized equipment is needed.

There are 4 main equipment categories that will be discussed as they apply to rodent surgeries: surgical instruments, lighting, magnification, and retractors. The standard set of instruments used for companion rodent species is smaller than those used for general surgery in the dog and cat, with smaller sizes being the size of choice. The standard set should include, at a minimum, 6 Jones towel clamps (2 in), 1 Adson dressing forceps (4.75 in), 1 Adson tissue forceps (4.75 in), scalpel handle (#31), 2 Hartman mosquito forceps (3.75 in, straight, 1- to 2-mm tip), 2 Hartman mosquito forceps (3.75 in, curved, 1- to 2-mm tip), 1 LaGrange scissor (4.25 in, curved), tenotomy scissor (4.25 in, blunt and curved), and 1 Olsen-Hegar needle holder (5.5 in). Ophthalmic instruments have been advocated but are not ideal,[8,9] even though the use of certain ophthalmologic instrumentation (e.g., forceps, needle holders) has been beneficial in the author's experience. Microsurgical instruments are ideal for small rodent surgery, but they are expensive, delicate, and require advanced skills to use in a proper manner. The microsurgical instruments are specifically designed for surgery in conjunction with magnification and are longer than ophthalmic instruments. They also have rounded handles so they can roll between the thumb and forefinger while the hand is at rest on the table. These instruments are well balanced and held like a pen, which reduces fatigue and tremors by the surgeon performing the procedure.[9]

Proper visualization of the surgical site is critical for veterinarians performing a surgical procedure on a rodent.[8,9] An adequate light source from an overhead surgery lamp should be available, but additional focal light sources attached to magnifying loupes, helmets, or headbands are extremely useful (www.surgitel.com). These focal light sources provide enhanced visualization of tissues, especially when combined with magnification. Because rodent patients are inherently small, magnification can facilitate visualization of the surgical site, which in turn may decrease surgery and anesthesia time. There are various magnification tools available. A 2× magnification is useful and recommended for beginners before considering an upgrade to higher magnification (3-5×). Magnifying loupes for hobbyists are inexpensive, but have poor quality optics, as one would expect. Loupes for surgical purpose are available as glasses or mounted on headgear. There are also a wide range of products that combine a focal light source and magnification on one headpiece.

Specialized retractors are critical, because even a skilled surgical assistant can hamper the surgeon's visualization of very small surgical fields.[8,9] The most useful is the Lone Star retractor (Lone Star Medical Products, Stafford, TX USA) and it consists of plastic rings of various sizes and shapes and rubber elastic stays with attached hooks. The elastic stays can be connected to the ring in a variety of configurations (Fig 1). A minor disadvantage with this method of retractor is that hooks may not be appropriate for every type of tissue, and hooks can inadvertently damage nearby structures. More specific instruments, for example those available for rabbit and rodent dentistry, are described elsewhere.[10]

Asepsis and Patient Preparation

Preoperative fasting is not usually practiced on rodent surgical patients because they do not vomit, and, because of their small size, they are predisposed to hypoglycemia. However, in rodent species that accumulate food in their cheek pouches (e.g., hamsters), it may be advisable to clean out the oral cavity to avoid accidental aspiration. Principles of surgical asepsis should also be applied in rodent surgery. Because rodent species may have an increased tendency to develop hypothermia during anesthesia, hair removed through shaving should be isolated to the surgical site only. It is very

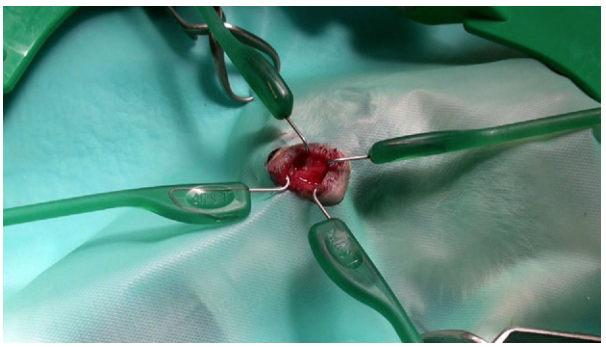

Figure 1. Semitransparent, nonadhesive plastic drape and Lone Star retractor. The patient is a 250-g citellus (*Spermophilus citellus*) undergoing excision of a facial abscess. Plastic drapes can be cut and contoured properly on patients and small surgical fields. Note the towel clamp fixes the surgical drape to the heating pad, not to the patient itself. Used by permission from Vittorio Capello, DVM.

challenging to evaluate the minimum surface area to be shaved on a rodent patient's body when prepping for dermatological or mammary tumor removal because the subcutaneous tissue is very loose and mobile. All solutions for cleansing, scrubbing, or rinsing should be properly warmed, whereas alcohol should be avoided to prevent hypothermia.[8,9]

Proper positioning of a rodent patient under anesthesia depends on the surgical procedure to be performed, and should be optimized so that both the anesthetist and the surgeon can access the patient. Most rodent species have a small thoracic cavity relative to their abdomen, and a small tidal volume. A reverse Trendelenburg position (i.e., slightly bent caudally) is recommended, whenever possible, for rodent patients placed in dorsal recumbency. This position will help reduce the pressure of the abdominal viscera on the thorax and facilitate their manipulation in case of laparotomy (Fig 2).

A severe disadvantage for the anesthetist monitoring rodent patients is the fact that the animal is completely obscured under standard surgical drapes. Plastic transparent (or slightly semitransparent) drapes are very useful in allowing the anesthetist to view the animal while still providing a sterile surgical field. Some transparent drapes are manufactured with an adhesive surface, which eliminates the need for large, heavy, or potentially traumatic towel clamps. Clear plastic drapes also help maintain body heat, and keep the patient dry from irrigation and flushing procedures. Keeping the patient dry represents one more advantage of clear plastic drapes over their fabric counterparts (Fig 1).

Hemostasis and Suture

Blood volume of small mammals is approximately 8 to 10 mL/100 g, and blood loss of 10% is considered safe in relatively healthy animals.[8] Proper hemostasis is critical, because even minimal hemorrhage during rodent surgery may adversely affect the patient's condition and may have a fatal outcome. Fine hemostats can be used, but may be too big or traumatic in very small patients. Standard ligation might be expensive or time consuming.[9] Compression hemostasis is more appropriate, and can be performed with sterile cotton-tipped applicators. Cotton swabs also provide 3 adjunct functions: they can be used to handle and bluntly dissect small and delicate tissue that cannot be grasped with forceps; they can be moistened with epinephrine for additional hemostasis; and they help to evaluate blood loss. Before surgery, measure the volume of liquid that can be absorbed by a single applicator; this will help one to estimate blood loss during surgery.[8,9]

Hemostatic clips provide effective hemostasis and are quick and easy to apply. Small and medium sizes are most appropriate for rodent surgery[8,9] (Ligaclip; Ethicon Inc., Somerville, NJ USA; www.ethicon.com). Gelatin sponge and oxidized regenerated cellulose enhance hemostasis, providing clot formation, are biolog-

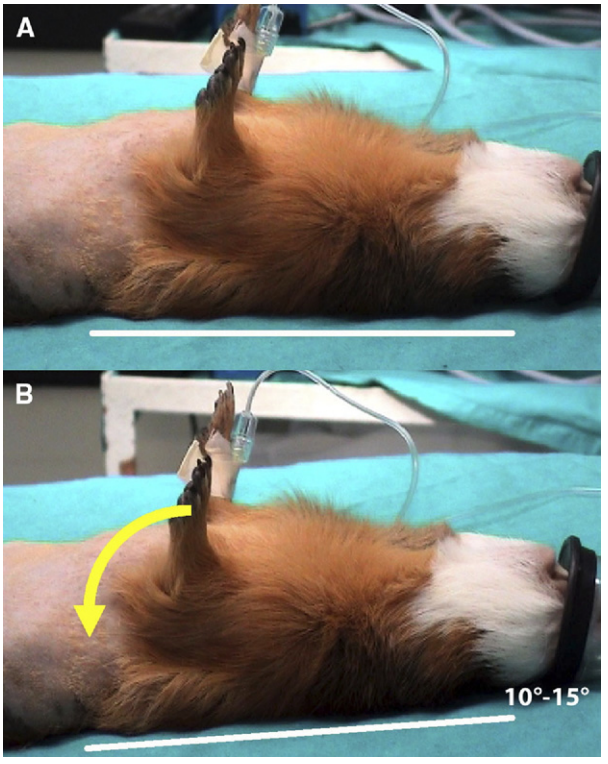

Figure 2. Female guinea pig prepared for ovariohysterectomy. (A) The horizontal position of dorsal recumbency and subsequent manipulation of viscera may lead to compression on the diaphragm and reduction of tidal volume, especially if the patient is not intubated and positive pressure ventilation is not an option. (B) Bending the surgical table caudally in a slight reverse Trendelenburg position helps to prevent this problem. Used by permission from Vittorio Capello, DVM.

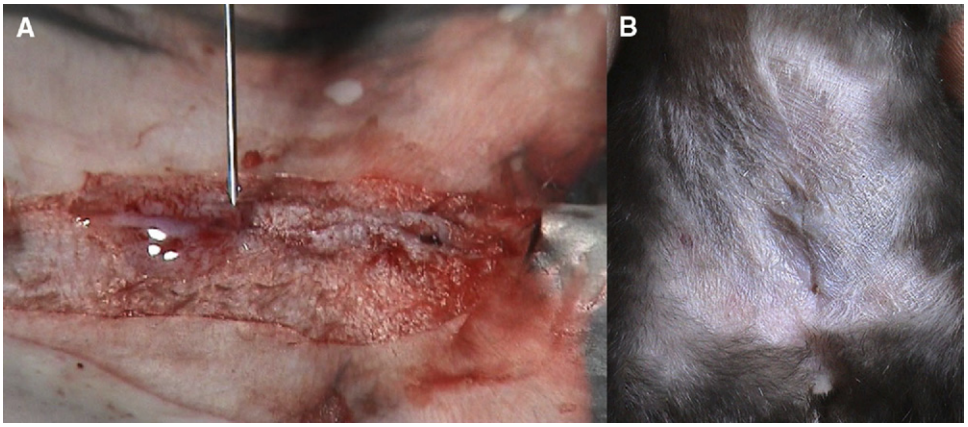

Figure 3. (A) Intradermic suture of the skin in a female hamster and application of tissue glue. (B) Follow-up after 7 days shows proper healing. Used by permission from Vittorio Capello, DVM.

ically inert, and adapt well to very small surgical sites (Surgicel, Ethicon Inc., www.surgicel.com; Tabotamp, Ethicon Inc., www.ethicon.com).

Radiosurgery represents the evolution of traditional electrocautery and low-frequency electrosurgery. In the latter, a platinum wire heated by electric current cuts and coagulates tissues, but the side heat generated can damage adjacent tissues of very small patients. Radiosurgery units use high (3.8-MHz) or ultra-high (4.0-MHz) frequency to vaporize intracellular water, accurately destroying cells[11] (Surgitron EMC; Surgitron Dual Frequency, Ellman International, Oceanside, NY USA, www.ellman.com). Collateral heat and damage are lower than with CO_2 laser units.[9,11]

Suture sizes of 4-0 to 6-0 USP are commonly used in rodents, although 3-0 sutures are appropriate for guinea pigs and other large rodents. Suture manufactured from synthetic materials absorbed by hydrolysis are preferred, and catgut should be avoided.[9] With the exception of the guinea pig, rodents have a tendency to disrupt and remove sutures. Depending on species, the use of Elizabethan collars is difficult, impossible, or carries several contraindications (e.g., increased stress, risk of entrapment, limited visual field, inability to carry out coprophagy). Nevertheless, the risk of postoperative self-trauma can be minimized with proper incision and handling of tissues, adequate size and type of suture material, surgeon skill, and effective analgesia. An intradermal suture pattern is the best option for skin closure, but requires surgeon skill and time. The use of skin staples will reduce closure time,[9] but published and anecdotal reports are contradictory to a desired healing effect in small exotic mammal species. Tissue glue, in combination with subcuticular suture, can be applied to the skin where traction is not present (Fig 3).

Common Surgical Procedures in Companion Rodent Species

The most common surgical procedures performed on companion rodent species involve the reproductive system (both elective and therapeutic) and the integument. Table 1 summarizes surgical procedures reported in companion rodent species.

Surgical Procedures of the Reproductive System

Removal of the reproductive organs in both male and female rodent patients is performed to achieve a preventative or therapeutic outcome. The 3 main indications for elective gonadectomy in both rodent sexes are control of reproduction; prevention of reproductive disease (especially in the female); and reduction of aggressive and territorial behavior in some species (e.g., prairie dogs). When control of reproductive activity between a pair of animals is the goal, an orchiectomy is usually the procedure of choice because it is considered to have a lower possibility for complications.[9] This is certainly true for smaller species, but invariably this reasoning leads one to underestimate the importance of neutering larger female rodents, including those in which reproductive disease has been extensively reported (e.g., guinea pigs, rats). Postoperative complications after neutering also depend on the surgical technique and the surgical approach. Because most diseases of the reproductive system are influenced by reproductive hormones, ovariectomy at an early age is expected to be as effective for prevention of future disease conditions (e.g., mammary tumors) as a complete ovariohysterectomy (OHE). An ovariectomy is

Table 1. Common surgical procedures performed in companion rodent species.

Organ system	Surgical procedure	Approach	Technique	Selected species for selected surgeries
Reproductive				
Male	Orchiectomy	Scrotal	Open	
			Closed	
		Prescrotal	Open	
			Closed	
Female	Ovariohysterectomy	Midline		
	Ovariectomy	Flank		
Urinary				
Male	Cystotomy			Guinea pig
	Ureterotomy			
Female	Cystotomy			
	Urethrotomy			
	Ureterotomy			Guinea pig
Digestive				
Dentistry				
Incisor teeth	Coronal reduction	Oral		
	Extraction			
		Intraoral	Transpalatal	Prairie dog
		Extraoral	Dorsal (Rhinostomy)	Prairie dog
			Lateral	Prairie dog
Cheek teeth	Coronal reduction			Elodont species
	Extraction	Intraoral/ Extraoral		
	Debridement of abscesses	Extraoral		
Prolapse of cheek	Reduction			Hamsters
	Amputation			Hamsters
Gastrointestinal disease	Gastrotomy			Guinea pig
	Enterotomy			
	Treatment of gastric dilation/volvolus			Guinea pig
	Reduction/Amputation of rectal prolapse			Hamsters
Integumentary	Skin biopsy			
	Excision of abscesses			
	Debidement of wounds			
	Excision of skin neoplasia			
	Excision of abdominal scent gland neoplasia			Gerbil
	Mastectomy			
	Amputation of the tail			
Muscoloskeletal	Fracture repair		Splinting	
			Intramedullary pinning	
			External fixation	
	Amputation	Forelimb		
		Hindlimb		
Ophtalmic	Enucleation of the eye globe			
Ear	Total ear canal ablation (abscessation of the ear canal)			
	Osteotomy of the tympanic bulla			Rat
Miscellaneous	Exploratory laparotomy			

easier to perform, and carries a much better prognosis than the OHE. Detailed knowledge of anatomy and physiology of the reproductive system of rodent species[9,12-14] is critical before performing these surgical procedures, and should not be extrapolated from dog and cat anatomy.

Orchiectomy. As with rabbits and other lagomorphs, the inguinal canals remain open throughout life in all rodent species, and testicles are free to move from the scrotum into the abdomen through the vaginal process because of a functional cremaster muscle.[9] However, unlike the rabbit, the inguinal canal of rodents is much wider and varies in size among the various groups of these animals. Rodent species are grouped in 3 different suborders: the Miomorph ("mouse-like" or "rat-like"); the Caviomorph ("guinea pig-like") or Hystricomorph ("porcupine-like"); and the Sciuromorph ("squirrel-like"). A true scrotal sac is present in miomorphs. In caviomorphs, the scrotum is a less separate anatomical entity and is in communication with the abdomen through a wider inguinal canal; it is better described as an appendix of the abdominal cavity. Testicles are located in the inguinal and perianal area, and the scrotal sac surrounds the anal opening. In sciuromorphs, the scrotal sac is even less visible, and testicles migrate more caudally during breeding seasons. They can be considered functional cryptorchids. Testicles of all rodent species are very large in proportion to their body size and have a well-developed epididymis, especially rats, and a large epididymal fat pad. Large seminal vesicles (e.g., in guinea pigs) and additional fat pads in the caudal abdomen partially occlude the inguinal opening, preventing scrotal herniation of abdominal viscera.[9] The specific anatomy found between rodent groups greatly affects surgical approaches and techniques when performing the orchiectomy procedure. Three different approaches are used for the orchiectomy in rodent patients: scrotal,[9,15-17] prescrotal,[18-20] and abdominal.[9,21] For the scrotal and prescrotal approach, 3 different surgical techniques can be performed: closed; open, with closure of the inguinal ring[9,15,18,19]; and open, without closure of the inguinal ring and with preservation of the epididymal fat pad.[9,15,20]

When performing an orchiectomy in rodent species, it is highly recommended to ligate the vaginal process, which passes through the inguinal canal. This will prevent potential herniation of abdominal fat, seminal vesicles, urinary bladder, or bowel.[18] In the author's experience, ligation of the vaginal process as it passes through the inguinal canal is particularly important in caviomorph rodent species. With the scrotal approach, either a double incision of the scrotal skin of each testicle, or a single longitudinal or transversal[9] excision allows exteriorization of testicles. With the closed technique, the vaginal process (tunic) is left intact and is bluntly dissected free from the subcutaneous tissue. Using a double or triple clamp technique, the vaginal tunic and the spermatic cord are transfixed and circumferentially ligated, and transected. The suture itself allows the closure of the inguinal canal. When using a double or triple clamp technique, special care must be paid to perform effective hemostasis because of the presence of an abundant epididymal fat pad. With the open technique, incision of the vaginal process is performed and the gonad is completely exposed. During this step, excessive cranial traction should be avoided to prevent exteriorization of a large amount of fat tissue and part of the seminal vesicles. Caudal traction allows eversion of the hemiscrotal sac and exposure of the tail of the epididymis, which is bluntly dissected from the tunic. The spermatic cord is clamped, ligated, and the testicle is removed. Rats have a well-developed deferens duct and vascular support; therefore, separate ligation of the spermatic cord and *ductus deferens* can be considered for appropriate suture of their vascular support.

The prescrotal approach provides clear advantages compared with the more common scrotal approach because it allows for more effective patient preparation.[18] Shaving, scrubbing, and draping are easier, which helps reduce the postsurgical incisional infections that are frequently reported in male guinea pigs. Postsurgical infections associated with guinea pig orchiectomies most likely occur because of the complex anatomy of their periscrotal pouch and the debris retained within it (Fig 4). Also, the prescrotal approach offers the best position for closure of the inguinal ring, which can be performed with a circumferential suture after blunt isolation of the vaginal process[18] or with a transfixing suture of the inguinal ring.[9,15] When the epididymal fat pad is preserved, there are references that do not recommend closure of the inguinal ring.[9,15]

The abdominal approach is more specific for young squirrels or adult individuals (e.g., squirrels, prairie dogs) out of the breeding season, where locating the testicle through the scrotal approach would be difficult. A standard, caudal laparotomy along the ventral midline is the preferred approach for an abdominal orchiectomy.[9] Once inside the abdomen, the urinary bladder is gently retracted and reflected caudally or laterally to each testicle. After the testicle has been located, the ductus deferens or the epididymal fat pad is grasped, allowing exposure of the testicle. Ligation of the spermatic cord, excision of the testicle, and closure of the incision are performed as routine.

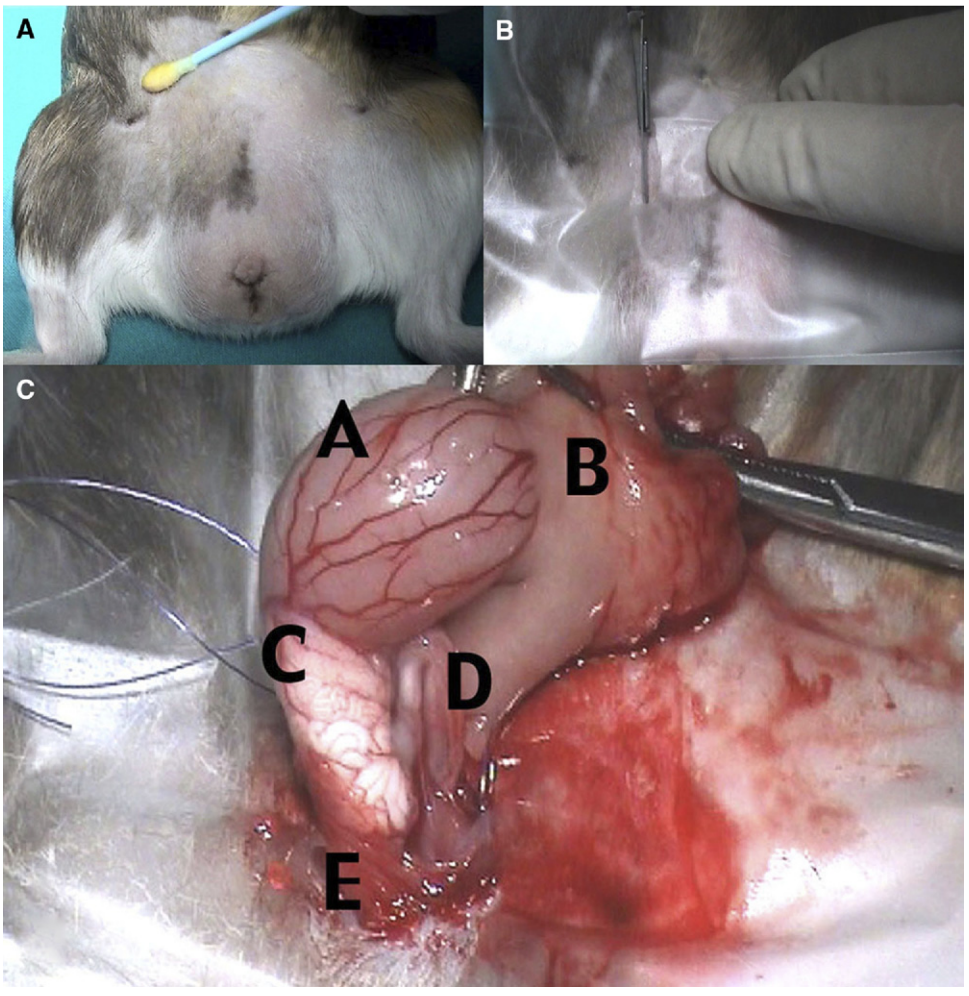

Figure 4. Orchiectomy in a guinea pig with the prescrotal approach and open technique. (A) The prescrotal area is shaved and scrubbed. (B) After the surgical field is draped with a self-adhesive transparent drape, a skin incision is performed a few millimeters lateral to the base of the prepuce. (C) Shown are: A) the exposed testicle; B) the spermatic cord surrounded by fat; C) the epididymis; D) the deferens duct; E) the everted hemiscrotal sac. Reprinted from Capello V: Prescrotal approach to elective orchiectomy in guinea pigs. Exotic DVM 8(5):29-32, 2006, with permission.

Ovariohysterectomy. There are many indications to perform therapeutic OHE in miomorph and caviomorph rodent species.[8,9,15,20,22-24] Indications for elective OHE are similar to those listed above for the male. From a general surgical standpoint, the surgical technique is not different from what is performed in dogs and cats; nevertheless, some differences must be emphasized. Unlike carnivores, rodent species do not have an ovarian bursa. As opposed to rabbits, rodents have a short vagina[14]; therefore, partial vaginectomy is not an option as in lagomorphs. Reproductive female organs are obviously much smaller, and significantly more friable in rodents. The muscular wall must be grasped with a forceps and slightly elevated before incision of the midline, because the large cecum lying just beneath the abdominal wall may be accidentally incised. Preventative OHE in caviomorph species is considered more challenging than in rabbit does because they are smaller patients and possess long and thin uterine horns, fragile salpinges, and a short ovarian suspensory ligament, making exposure of ovaries more difficult from the midline approach.[25] For these reasons, the flank approach for ovarian removal is a recommended alternative in caviomorphs.[8,9,25,26] The flank approach for ovarian removal offers many advantages. Two laparotomic incisions are necessary, but they are much shorter than the ventral midline incision needed for visualization of the ovary and entire reproductive tract. The author prefers 2 separate skin incisions, but a single midline dorsal incision (shifting the loose skin alternatively from one side to the other) is a possible option, especially in rats.[8,9,26] With the flank approach, the suture line is easier to evaluate, the incision is less likely to become contaminated from bedding, dehiscence and potential evisceration are reduced, the surgical procedure is shorter, and manipu-

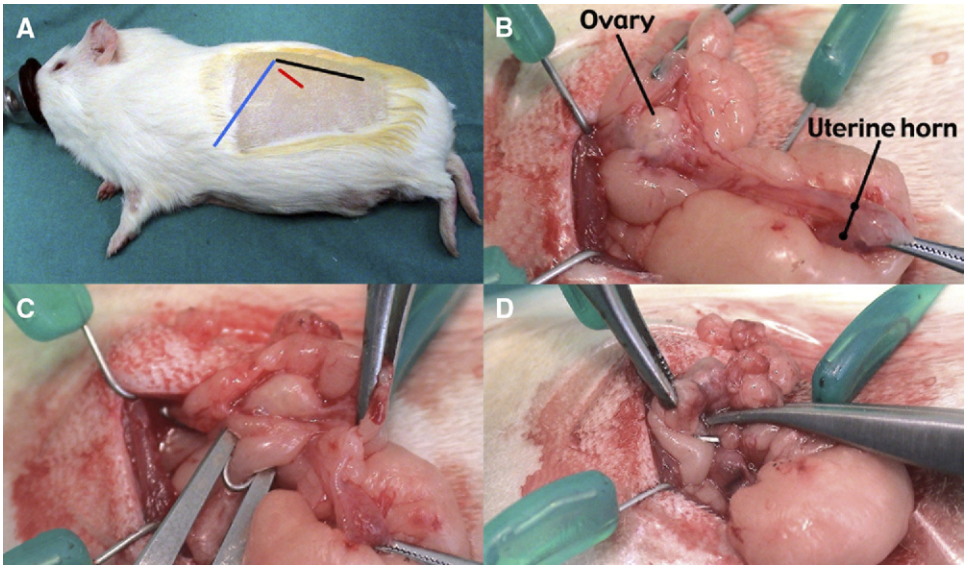

Figure 5. Ovariectomy in a guinea pig with the approach from the flank. (A) The points of reference for incision of the skin and the abdominal wall (red line) are represented cranially by the edge of the last cartilaginous ribs (blue line), and dorsally by the line of the lateral vertebral processes (black line). (B) The ovary and proximal tract of the uterine horn are easily exposed with gentle traction of the fat. (C) The ovarian vessels are ligated with hemostatic clips. (D) The ovary is dissected with blunt scissors and removed. Reprinted from Capello V: Flank approach to elective ovariectomy in guinea pigs. Exotic DVM 8(5):33-37, 2006, with permission.

lation of the abdominal viscera is minimal, with reduced risks of gastrointestinal stasis and adhesions. For the reasons stated above, postoperative pain is also significantly reduced. One disadvantage of the flank approach is the inability to perform an exploratory laparotomy and a complete hysterectomy, but these concerns are often insignificant when the procedure is for elective neutering.

For the flank approach, an incision of the skin and the abdominal wall is made between the last cartilaginous ribs and the lateral processes of the lumbar vertebrae. The subcutaneous tissue and the muscular wall are then bluntly dissected. Hemorrhage is minimal and can be easily controlled. The ovary, the salpinges, and the proximal tract of the uterine horn are easily exposed with gentle traction of the exposed fat. After compression of the vessels with a hemostat, the author prefers standard hemostasis of the ovarian artery by clipping or ligation. The ovary is removed, and a 2-layer closure is performed (Fig 5).

In case of debilitated patients needing a therapeutic OHE, the standard surgical procedure carries a guarded prognosis and a relatively high mortality rate. In these cases, a less stressful surgical option may be offered to the pet owner by performing 2 shorter and less invasive procedures: total hysterectomy from a shorter, caudoventral midline approach; followed by ovariosalpingectomy from the flank as soon as the patient recovers and can withstand the stress of a second surgery.

Caviomorph rodents give birth to large offspring and are prone to dystocia, which is extremely rare in other groups of rodents. Caesarean section is indicated after prolonged labor and no response to 0.5 to 1.0 IU of oxytocin. Depending on the owner's choice and other clinical factors, the uterus may be closed with appropriate suture patterns or removed after the fetuses are delivered.[9]

Surgical Procedures of the Urinary System

Urolithiasis is a common disease in guinea pigs and has been reported less frequently in other rodent species.[8,9] Uroliths are commonly located in the urinary bladder or the distal ureters. Calculi appear to occur less frequently at the level of the male urethra and the female ureters. Unilateral nephrolithiasis is rare, and to the author's knowledge a nephrectomy has not been reported on a companion rodent species. Preoperative localization is critical, because ureteral stones are not easily manipulated into the urinary bladder without risk of significant trauma (or, depending on size, they cannot be manipulated at all). Therefore, the surgeon should be prepared to perform a ureterotomy.

A standard cystotomy procedure is performed with a ventral incision after isolation of the bladder with saline solution–moistened gauzes. Additional stay sutures are placed for easier handling of the bladder. Full-thickness, continuous inverting suture is performed

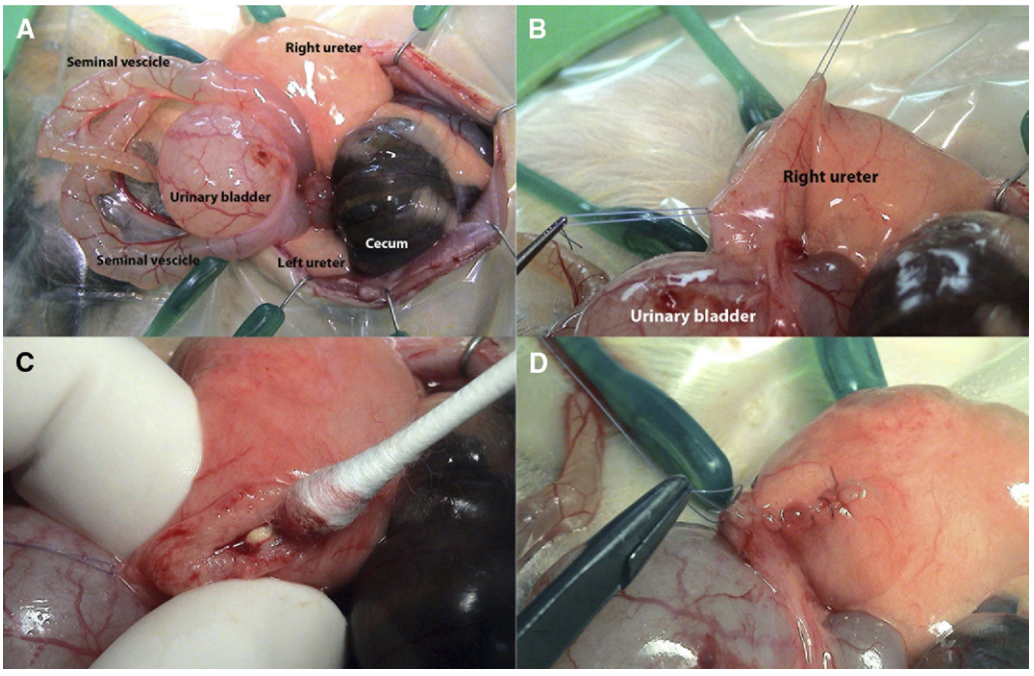

Figure 6. Ureterotomy in a male guinea pig. (A) Surgical access to the distal right ureter via caudal laparotomy on the ventral midline. Proper exposure of the urinary bladder and of the seminal vesicles is needed to access the ureters. The ureters are normally embedded in fat. (B) Two stay sutures have been preplaced in the serosal surface of the distal ureter where the uroliths were present. (C) Ureterotomy. Hemorrhage is controlled with cotton-tipped applicators. (D) A single layer closure is performed with 5-0 monofilament absorbable suture in a continuous pattern. Used by permission from Vittorio Capello, DVM.

with absorbable 4-0 or smaller suture material. The ureterotomy procedure is much more challenging than that of a standard cystotomy, and requires specialized equipment similar to instrumentation used for vascular surgery. The ureterotomy incision should be closed with 6-0 or smaller suture material (Fig 6). Large stones may be located at the level of the distal urethra in the female, where they often lodge in the blind *preputium clitoridis* and slowly increase in size rather than move distally along the urethra. These large stones in the distal urethra of female patients may be removed through a small incision, with the help of a rigid endoscope, or via lubrication and gentle manipulation.

Although rarely performed, a urethrostomy procedure was described in a rat.[27] The surgery was executed after excision of a preputial adenocarcinoma and subsequent penile amputation.[27]

Surgical Procedures of the Digestive System

Dental Procedures. Dental procedures are included among the topic of general rodent surgery for at least 2 reasons: 1) even for cases of simple intraoral dental procedures, patient preparation and intraoperative/perioperative support are very similar to other surgical procedures, and 2) many dental procedures have an increased surgical component (e.g., extraoral tooth extraction, debridement of abscesses). Detailed discussion of those techniques is beyond the scope of this article; however, dental procedures associated with rodent surgical presentations are reported elsewhere.[10,28]

Surgical treatment of pseudo-odontomas in prairie dogs deserves special mention. The pseudo-odontoma is a non-neoplastic, acquired malformation occurring when normal eruption of elodont incisor teeth are impaired or arrested. Apical growth continues, causing primary deformation of the apex and reserve crown, and secondary abnormalities of the surrounding incisive bone. The outcome is severe apical deformity acting as a space-occupying mass protruding from the rostral portion of the nasal cavities, leading to progressive obstruction in these obligate nasal breathers.[29] Different surgical techniques have been reported for treating this condition in prairie dogs. The goal of primary treatment is extraction of the affected maxillary incisor tooth or teeth. The standard technique for extraction is similar to that described for rabbits, but is extremely challenging in prairie dogs because apical deformities and dental ankylosis are always present to some degree.[30] The most common complication is frac-

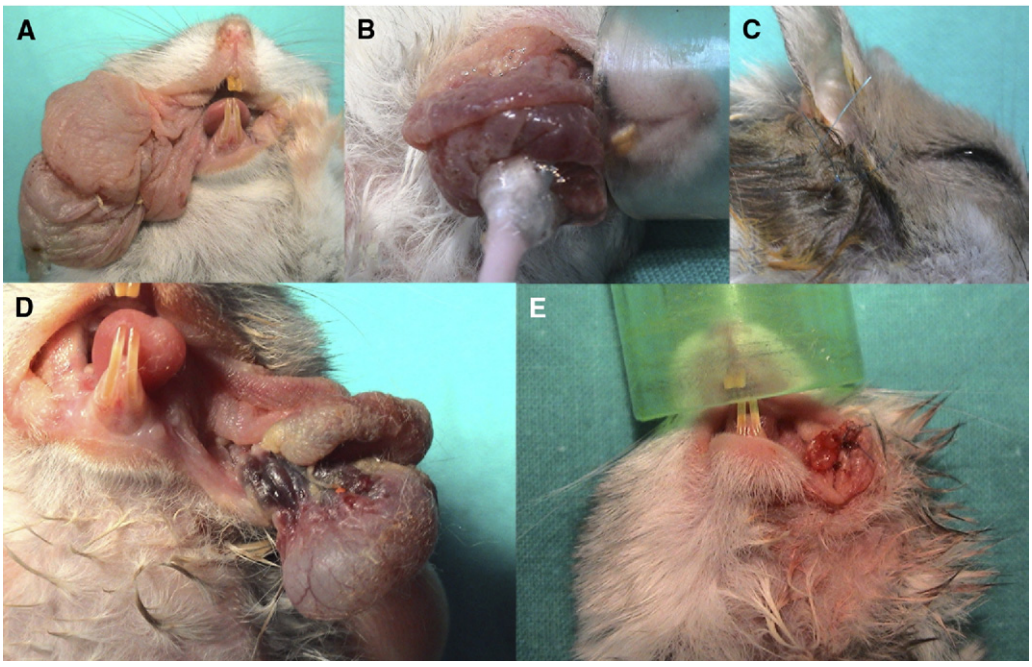

Figure 7. Surgical procedures for prolapse of cheek pouch in Russian hamsters. (A) Prolapse of the right cheek pouch. (B) Prolapse is reduced with cotton tip applicators. (C) A transfixing suture is placed to prevent the tissue from reprolapsing. (D) In cases with severe mucosal lesions, amputation of the cheek pouch is recommended. (E) Suturing the mucosa. Used by permission from Vittorio Capello, DVM.

ture of the tooth, which would represent treatment failure. In cases where there is a tooth fracture, an intraoral, transpalatal approach to the apexes can be considered.[29] An alternative approach is the dorsal approach to the apical mass by rhinotomy.[29] Depending on the case, the apical mass can be removed entirely or simply debulked. A lateral approach (unilateral or bilateral) to the apical mass burring through the lateral surface of the incisive bone has also been described,[29] and in the author's experience seems to be a promising surgical option. Palliative treatment by dorsal rhinostomy and positioning of a tubular stent can be considered when the goal is to perform a shorter and (to some extent) less invasive surgery that minimizes risks related to anesthesia and surgical treatment.[31] However, this option does not stop the dysplastic process.

Diseases of cheek pouches include impaction, prolapse, abscessation, and neoplasia.[23] Prolapse of cheek pouches, due to overfeeding, is relatively common in Russian hamsters (Fig 7). Retained food becomes adherent to the mucosal surface of the cheek pouch, and when the hamster empties it, the pouch prolapses along with the food. If the prolapse is recent and there are no lesions on the mucosal surface, repositioning can be attempted with the patient under general anesthesia by rehydrating the prolapsed mucosa with saline solution and lubricating it with lidocaine gel. The pouch is gently replaced with cotton swabs, and apposition of a transfixing suture through the skin and the cheek pouch is performed to prevent reoccurrence.[8,9,23] Cheek pouch amputation is considered in cases of severe mucosal lesions, recurrent pouch prolapse, or neoplastic disease. In uncomplicated cases of prolapse, a hemostat is placed at the base of the pouch, and the tissue is transected and sutured.[23] When a cheek pouch mass has been diagnosed as neoplastic, delicate blunt dissection and careful hemostasis are performed while amputating the affected cheek pouch.

Gastrotomy for surgical treatment of hairballs in guinea pigs and enterotomy for several intestinal conditions (e.g., obstruction and intussusception) have been anecdotally reported in rodent patients. Golden hamsters are prone to colon or rectal prolapse after intestinal parasitism, enteritis, and proliferative ileitis ("wet tail").[8,23] Rectal prolapse can be replaced when severe mucosal lesions are not present. A purse-string suture is carefully placed around the rectum to make sure the affected tissue remains in place. The purse string suture should be monitored by a veterinarian to confirm the passage of fecal material. Necrotic prolapsed tissues must be amputated and exploratory laparotomy is recommended to resolve bowel intussusception, which is frequently associated with rectal prolapses.[8]

Surgical Procedures of the Integumentary System

Skin biopsy, removal of neoplastic tissue(s), and debridement of bite wounds and subcutaneous abscesses represent common indications for rodent dermatological surgical procedures. Excision performed with blunt dissection and standard skin suture is usually simple because of abundant loose subcutaneous skin. Nevertheless, selected cases might be much more challenging because neoplasia can be infiltrative, growing to a large size (up to 50% of the body weight), and it may be difficult to obtain clean margins on the excised mass.

Both benign and malignant mammary tumors occur in many rodent species (including males).[9] Surgical excision of mammary neoplasia is the most common procedure performed on female rat patients. Rat mammary tumors are mostly benign fibroadenomas and they rarely metastasize; therefore, surgical treatment often carries a good prognosis for survival.[8,9,32] Clinical signs are related to rapid growth and size of the neoplastic mass. Excision consists of careful blunt dissection and hemostasis, and is usually uncomplicated (Fig 8). The tumor's blood supply is often limited and easily ligated. Masses located in the ventral caudal abdomen may encompass the vaginal and urinary orifices. Even in these cases the tumor can be carefully excised from the urethra and vagina, which can be identified by inserting a blunt probe into each orifice. Concurrent ovariectomy or OHE is recommended[8,9], although the beneficial effects relating to decreased hormonal levels at this point in the rat's life are unknown. Depending on position, and because of loose subcutaneous tissue, a laparotomy may be performed through the same skin incision used for excision of the neoplastic mass. Skin staples provide a rapid method for extensive suture of the skin in a single layer, significantly decreasing the length of time required for the surgical procedure.[8,9] Another specific, relatively frequent, condition requiring extensive excision and debridement of rodent skin is cervical lymphadenitis of guinea pigs.[8]

Rodent species with long tails (e.g., gerbils) are prone to degloving injuries when they are inappropriately restrained (e.g., grabbing them by the distal portion of the tail).[8,9] This problem occurs most frequently in degus, gerbils, mice, and chipmunks. Aseptic necrosis of the distal portion of the tail is also relatively common in mice. If caudal vertebrae remain exposed, amputation is recommended. The surgical procedure to amputate a rodent tail is straightforward; the skin is incised and sutured more distally than the amputation of the caudal vertebrae, thereby providing sufficient skin to cover the vertebra. The desired length of the tail after amputation should be discussed with the owner before surgery, even if the amputation at the base of the tail is recommended to prevent the reoccurrence of the same lesion.

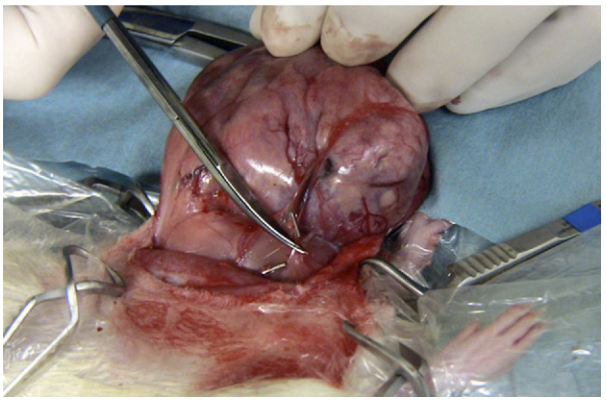

Figure 8. Excision of a mammary tumor from a rat. The mass is bluntly dissected after clipping the vascular support to the tumor. Used by permission from Angela Lennox, DVM.

Orthopedic Procedures

Orthopedic lesions are common in pet rodents, with most presentations being traumatic in origin. Typically, orthopedic presentations of rodent patients are the result of the animal being dropped by the owner, stepped on, or sat on. Rodents also often suffer injuries secondary to entrapment in cages.[23,33] Many traumatic orthopedic injuries are long bone fractures, with fractures of the tibia, both open or closed, representing the most common presentation. Whenever possible, the option of fracture repair should be considered and proposed to the owner. In many cases the pet rodent may be presented days or weeks after the initial injury has occurred. Despite successful repair having been performed in many rodent patients, some even as small as Russian hamsters, patient size often represents a limiting factor. The use of external fixation and intramedullary pins has been reported in limb fracture repair of rodent patients (Figs 9 and 10).[23,33-36]

Amputation of limbs in exotic companion rodent species may be necessary when bony or soft tissue lesions cannot be managed with orthopedic surgery or splinting; when osteomyelitis after open fractures or surgical failure occurs; and in cases of neoplasia.[33,34] Amputation has been successfully reported in many different rodent species for both thoracic and pelvic limb injuries, the latter being the most frequent (Fig 11).[23,33,37-39] The prognosis of every single case in which amputation is being

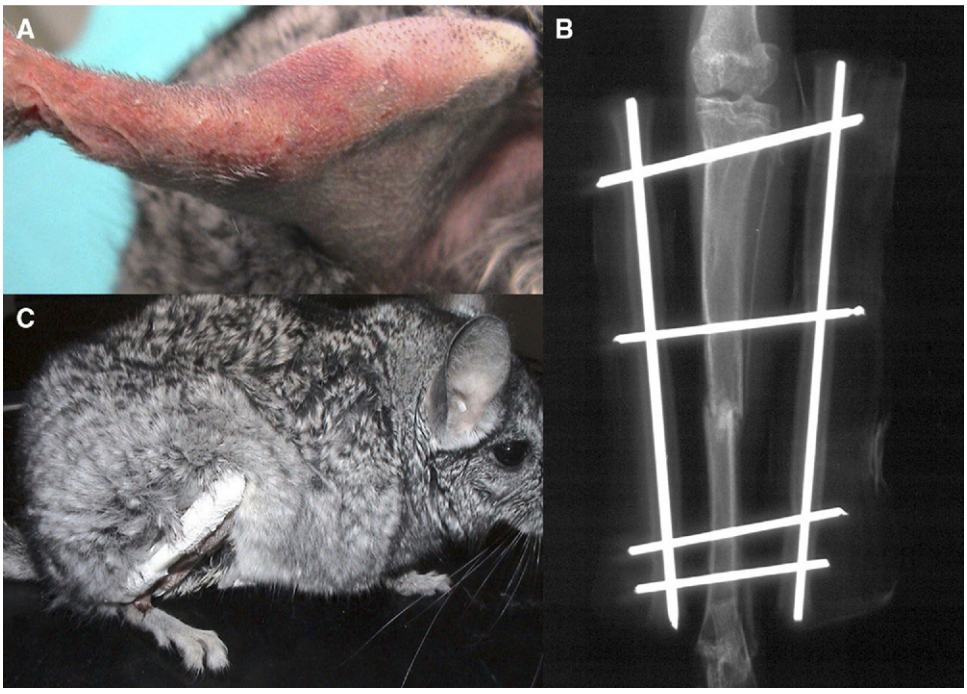

Figure 9. Osteosynthesis of a midshaft tibial fracture in a chinchilla using a bilateral external fixator. (A) Clinical aspect of the tibial fracture, with the limb shaved before surgery. (B) Postoperative radiograph. The tibial fracture is properly aligned in the anteroposterior projection. (C) The chinchilla using the limb after surgery. The foot appears slightly rotated (laterally) because of interference of the medial bar of the external fixator. Reprinted from Capello V: External fixation for fracture repair in small exotic mammals. Exotic DVM 7(6):21-37, 2006, with permission.

considered should be based on the rodent species, husbandry, and patient health status. The level of amputation depends on the injury and surgeon's preference. Cosmetic appearance is not typically a concern for very small and fully furred mammals. Amputation of the forelimb in rodent species having cheek pouches might lead to impaction of the homolateral cheek pouch, and prevention of this condition should be discussed with the owner before surgery.

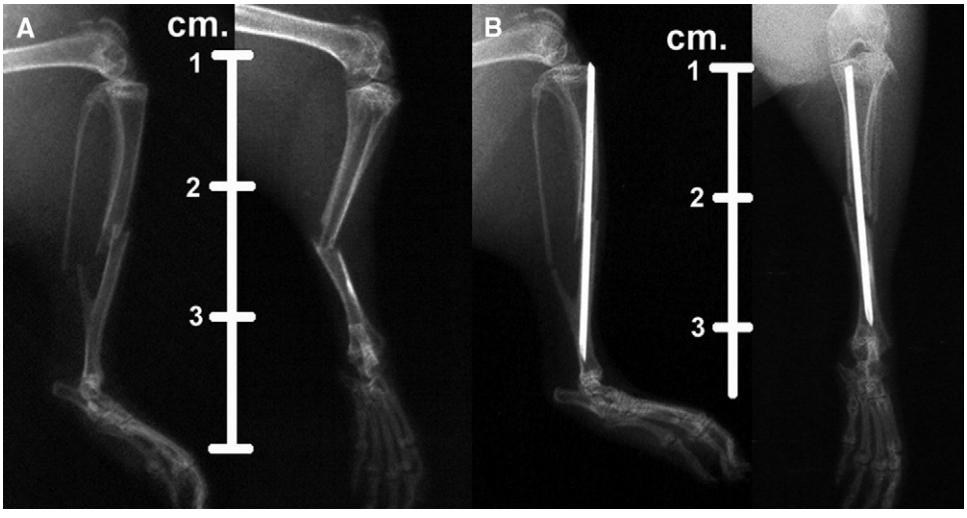

Figure 10. Osteosynthesis of a midshaft tibial fracture in a golden hamster with an intramedullary pin. (A) Fracture of the tibia and fibula; lateral and craniocaudal projection. (B) Intramedullary pinning using the needle from a 22-gauge intravenous catheter; lateral and craniocaudal projection. Reprinted from Capello V: External fixation for fracture repair in small exotic mammals. Exotic DVM 7(6):21-37, 2006, and Capello V: Surgical techniques in pet hamsters. Exotic DVM 5(3):32-37, 2003, with permission.

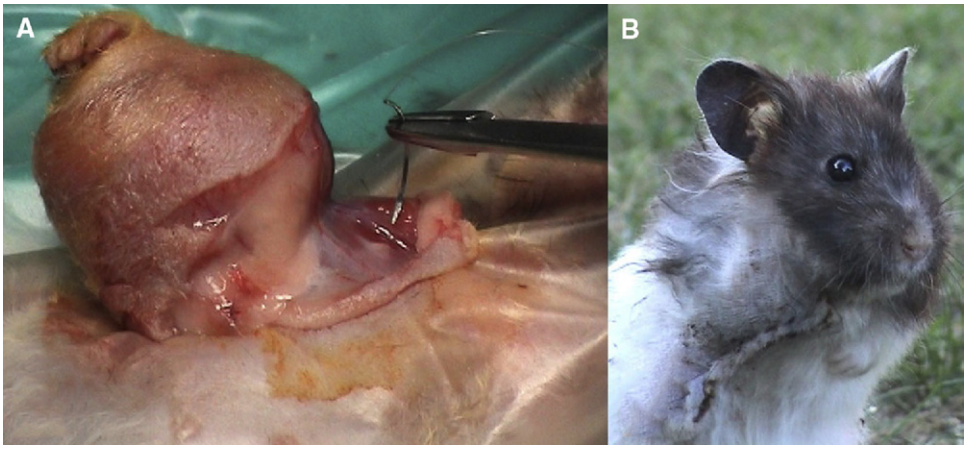

Figure 11. Amputation of the neoplastic forelimb in a golden hamster. (A) Suture placed around the brachial artery. (B) Follow-up 7 days after surgery. Used by permission from Vittorio Capello, DVM.

Surgery of the Eye, Ear, and Respiratory System

Some rodent species have prominent eyes (e.g., hamster), therefore these animals are predisposed to panophthalmitis and other severe ocular conditions caused by traumatic injuries, bites from cage mates, and bacterial infections which may or may not follow respiratory or dental disease.[8,9,23] Although some cases may progress to *phthisis bulbi* or aseptic necrosis, enucleation is recommended in many cases to prevent ascending complications through the optic nerve. Depending on the condition of the eyelids, enucleation can be performed with a transpalpebral or transconjunctival technique.[8,9,23] The transconjunctival technique is the most common enucleation technique used for rodents. To perform the transconjunctival procedure, the conjunctival mucosa is incised, after which the sclera and the external muscles of the globe are bluntly dissected. Rodents have a large venous sinus, and careful hemostasis must be achieved. Dissecting close to the eye globe, the transconjunctival technique may allow preservation of the sinus. Also, it provides a better cosmetic outcome.[8] After enucleation, eyelids can be surgically debrided and sutured in an simple interrupted pattern.

Otitis externa and otitis media have been reported in rodents, especially in rats and hamsters.[23,40,41] Otostomy, total ear canal ablation, and bulla osteotomy are all surgical options to be considered depending on the case presentation and expected prognosis after surgery (Fig 12).

As mentioned above, rhinostomy (with or without application of a stent) is a surgical option in prairie

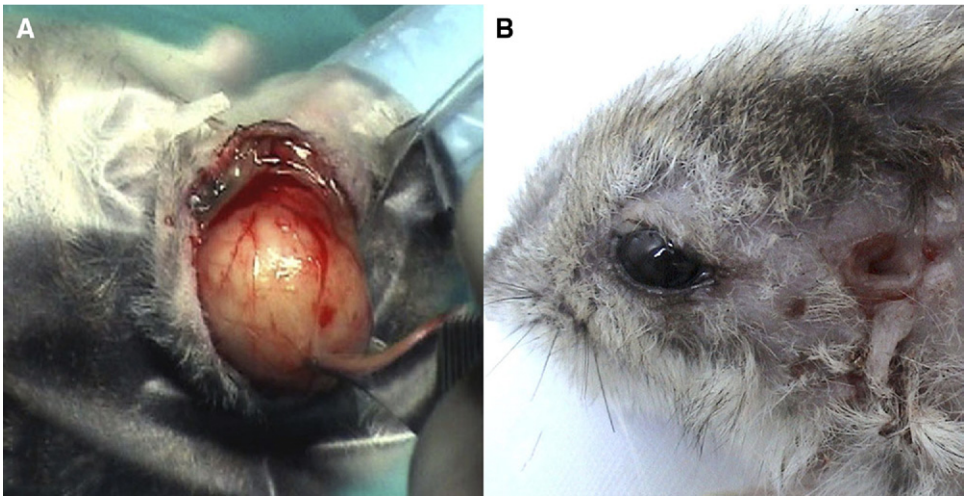

Figure 12. Total ear canal ablation and amputation of the ear pinna in a Russian hamster. (A) Excision of the abscessed ear canal. (B) Follow-up 10 days after surgery. Used by permission from Vittorio Capello, DVM.

dogs affected by pseudo-odontoma. Lobectomy in the case of pulmonary abscess of rats could be considered a surgical option, but is not practical because of patient size and the general level of difficulty to perform the procedure.

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