Gross and Surgical Anatomy of the Reproductive Tract of Selected Exotic Pet Mammals

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Abstract: Elective and therapeutic surgery of the reproductive tract of exotic pet mammals is common. Wide anatomical differences among exotic pet mammals make knowledge of comparative anatomy of the reproductive tract of critical importance. Indications for elective surgery include prevention of reproduction and undesirable reproductive behaviors, as well as disease prevention.

Introduction

Exotic companion mammals include many different species belonging to different Orders: carnivores (Carnivora); rabbits (Lagomorpha); rodents (Rodentia); Artiodactylids (Artiodactyla), and insectivores (Insectivora). Also included are some species of non-human primates (Primates) and bats (Chiroptera). Recently, some species of the mammal subclass of marsupials (Marsupialia) have also been introduced as pets.

Fortunately, time has long past when practitioners treated the first "non-conventional"species such as ferrets, rabbits, and few rodents as simply smaller dogs and cats. It is now clear why veterinarians who include exotic mammals into practice need a clear understanding of the anatomy and physiology of so many different species. Both the "standard of care" practiced by exotic animal veterinarians and the level of care demanded by exotic animal owners is increasing. Elective surgery is performed more frequently; therefore, the knowledge of the surgical anatomy is extremely important.

This presentation discusses the comparative gross and surgical anatomy of the reproductive tract of the ferret and skunk; rabbit and selected species of rodents; sugar glider and Virginia opossum; as well as the potbellied pig and hedgehog. A brief discussion of the different neutering techniques and indications for elective neutering will be discussed as well.

Ontogenesis of the Reproductive Tract

A quick review of the ontogenesis[1] of the reproductive system is often useful for a better understanding of the anatomical differences between exotic mammal species. The urinary and the reproductive system originate from the same mesodermic structure. The development of the proximal organs is independent; however, the distal tracts maintain a close relationship for the rest of their development and life. The early formation of the reproductive tract is the same for both genders.

The gonads originate from the genital crest; the genital tracts develop from the mesonephric duct (also called the Wolffian duct) and the paramesonephric duct (also called the Mullerian duct); the external genitalia develop from the primitive cloacal region.

During the undifferentiated phase, the Mullerian ducts–paired and symmetrical–lie medially to the Wolffian ducts and fuse together distally into the primitive distal urogenital sinus; the Wolffian ducts–paired and symmetrical–lie lateral to the Mullerian ducts and enter the distal urogenital sinus.

In the male, the proximal tract of the Wolffian duct becomes the epididymus, and the distal tract develops into the deferent duct. The Mullerian ducts regress almost completely, with the exception of the distal tract which becomes the prostate gland. Changes in the ligaments of the gonad and of the ventral abdominal wall lead to the descent of the testicles, which usually begins after birth.

In the female, the Mullerian ducts become the genital duct, and differentiate into the salpinges, the uterine horns, and the vagina. The Wolffian ducts regress. The primitive cloaca is divided by the formation of a septum. Dorsally, it delimits the distal tract of the intestine, and ventrally the urogenital sinus.

The external genitalia originate from 2 different structures: 1) the genital tubercle in the ventral part of the abdomen and 2) the primitive urogenital ostium. The size of the genital tubercle increases considerably in males, becoming the penis with the urethra; in the female, it remains small and becomes the clitoris. The primitive urogenital ostium becomes a groove, surrounded laterally by 2 folds. From these folds, the scrotal sacs will develop in the male, while the labia majora of the vulva will develop in the female. In most pet species, they will then regress, and remain the labia minora.

The kidney develops from the primitive pronephros (which in mammals regresses very early) in stages to stages to form the mesonephros and the metanephros. The primitive ureters of the mesonephros are the Wolffian ducts, which will develop later into the male genital ducts. From the distal part of the mesonephric ducts, the ureteric bud will develop, becoming the secondary or definitive ureter. The cranial part of the urogenital sinus, where the secondary ureters end, enlarges and becomes the urinary bladder. In this phase the primitive urinary bladder is still connected with the allantois through the allantoic pedicle. The short tract of the urogenital sinus between the opening of the mesonephric ducts and the opening of the secondary ureters becomes the definitive urethra in the female, while in the male this will form the proximal tract of the urethra. (Most of the urethra will origin from the development of the genital tubercle.)

Important modifications occur during ontogenensis of the genital system of different mammal species (especially between the more familiar placental and the marsupial species), leading to anatomical peculiarities that have significance for the practitioner considering surgery of the reproductive tract.

Marsupial Mammals

The urogenital tract of marsupials demonstrates the most significant anatomical differences compared with placental mammals.[2] In marsupials, final development of the ureters places them medial to the genital ducts, while in placental mammals the ureters course laterally. The presence of the ureters prevents fusion of the distal part of the genital ducts into a single uterine body in the female, as is present in most placental mammal species.[2,3]

For this reason, the uterus is completely paired, and divided into 2 uterine horns (or uterine bodies). The 2 separate genital ducts continue distally, actually forming 2 separate vaginas, termed “lateral vaginas.” Due to the presence of the ureters on the medial aspect, the lateral vaginas cannot fuse together, but become united just ventral to the ureters, into an anatomical structure called the “median vagina.”[2,3] In reality, the term “median vagina” is controversial, because this structure continues distally into the urogenital sinus, which is the remnant of

the primitive cloaca. The uterine horns have 2 separate cervices, like the rabbit, and enter the median vagina. The urinary bladder is positioned ventral to the median vagina and to the urogenital sinus. The division is marked by the urethra, which opens caudoventrally, and by connective tissue between the median vagina and the urogenital sinus. In most marsupial species, the birth canal is transient, and is recreated at each birth, while in other species it remain patent after the first birth.

The distal tract of the ureters enters the urinary bladder crossing the median vagina laterally.

The urogenital sinus opens externally through the urogenital opening. Because it is very close to the anal opening, this orifice is also called the cloacal opening.

The peculiarity of the external genitalia of male marsupials (in common only with lagomorph species among placental mammals) is that the scrotal sac is well developed and located cranial to the penis, and to the urogenital opening. The tip of the penis of the sugar glider is forked.

The anatomical peculiarities described above impact surgical techniques for neutering and spaying pet marsupials. Orchiectomy is straightforward and the testicles can be easily accessed through a single scrotal incision. Nevertheless, the pendulous appearance of the scrotum suggests ablation could be indicated as well.[4,5]

The surgical technique for neutering the female is more challenging. Anecdotally reported infections of the genital tract of female captive Virginia opossum suggest that elective neutering may be important in this species kept as a pet. As in placental mammal species, it is probably ideal to remove as much reproductive tissue as possible. Therefore, neutering of the female opossum, (and the rabbit as well) is better termed ovario(salpingo)hysterovaginectomy.

The position of the distal ureters as they cross the median vagina before entering the urinary bladder makes removal of the paired lateral vaginas together with the uterine horns impossible. Therefore, ovariohysterovaginectomy is performed in 2 steps: ovariohysterectomy followed by vaginectomy of the 2 lateral vaginas.

Placental Mammals

Anatomical peculiarities of placental mammal species following ontogenetic development have different significance in male and female animals. In males, the most important are related to the descent of the testicles. Soon after descent of the testicles into the scrotal sac, the paired distal openings of the abdominal wall–the so called "inguinal rings"–close in all species except lagomorphs and rodents. In these species, the inguinal rings are patent throughout the life of the animal, and they allow each testicle to move from the homologous scrotal sac to the caudal part of the abdominal cavity and vice versa.[6–10]

In female species, the extent to which the primitive Mullerian ducts fuse distally and the development of the urogenital sinus determine some of the significant differences in the anatomy of the vagina, the urethra, and the uterine cervices.

Indications for surgical alteration in rabbits and rodents

Indications for elective surgical alteration in rabbits and rodents include prevention of breeding and reduction of hormone-related aggression. Hormonal aggression appears most common in female rabbits, but is of negligible concern in female guinea pigs. Some, but not all, male rabbits display undesirable sexual behavior directed toward

owners, other pets, or objects. Undesired sexual behavior is rare in male guinea pigs and rodents, but male guinea pigs may display dominance with other males in the group. Both intact male and female rabbits may spray urine outside the litter box. Owners also report increased aggression among intact female and male rabbits, male mice, and occasionally male guinea pigs. Surgical alteration often greatly reduces unwanted sex-related behaviors, but may not eliminate them entirely.

Additional indications include prevention of uterine neoplasia in female animals, in particular rabbits, and ovarian cysts in female guinea pigs. Intact female rabbits are especially prone to neoplasia of the reproductive tract, but also pyometra, hydrometra, and reproductive cysts and abscesses. Incidence of uterine adenocarcinoma is high, with one study reporting 60% in animals over 4 years of age.[11] For this reason, and for elimination of hormone-related aggression, surgical alteration is highly recommended in female rabbits.

Ovarian cyst formation is a common problem in older guinea pigs, with an incidence in one examined population of 76%, mostly in pigs between 2 and 4 years of age.[12] Cyst size varies, but very large cysts can produce general debilitation, presumably due to discomfort of space-occupying mass. Some cysts are accompanied by symmetrical alopecia. Serous cyst formation is a normal component of the ovarian cycle in female guinea pigs, and can be experimentally induced with estrogen.[13,14] A study investigating links between breeding history, age, cyst prevalence, and size showed no relationship between breeding history and cyst formation, but a significant relationship between cyst size and prevalence and age.[15] FSH has been shown to have some anti-cystic effects in experimental guinea pigs.[14] More data on the incidence of debilitating cysts in pet populations is needed in order to better evaluate the risk/benefit of early ovariohysterectomy for the prevention of ovarian cysts in this species.

Ovariohysterectomy has been proposed for prevention of mammary tumors in rats. The incidence of mammary tumors in specific lines of laboratory rats ranges from a low of 3.1% in males to 27% in females.[16,17] The author was unable to find statistics on the incidence of mammary tumors in pet rat populations, or scientific data on the efficacy of ovariohysterectomy for prevention of spontaneously occurring mammary tumors in pet rats. Laboratory studies on the hormonal effects of mammary tumor development are conducted on specific laboratory strains with chemically induced tumors that are not the same as those spontaneously occurring in pet rats. Therefore, extrapolation of these studies to pet rats should be done with caution.

Rabbits: male

The urogenital anatomy of male rabbits is unique among placental mammal species, and common in marsupial species.[6,7] The penis is located caudal to the testicles, which lie cranial to the penis in 2 separate hemiscrotal sacs. The other important anatomical peculiarity, mentioned above and in common with rodent species, is the open inguinal canal, making rabbits (and rodents) "functional cryptorchids." Position of the testicles depends on many factors including body position, body temperature, breeding activity, gastrointestinal tract filling, and the amount of abdominal fat. The testicles of rabbits are elongated and not round. The epididymis is clearly visible at the caudal pole of the testicle, but not as developed as in rodent species. There is also significantly less peri-testicular fat than in rodent species. The glans of the penis is not well developed, is tapered, and covered by a prepuce.[7]

The 2 main anatomical peculiarities of male rabbits have important implications in regard to orchiectomy. Ligation of the open inguinal canals is highly recommended during the surgical procedure in order to prevent hemiscrotal herniation of abdominal viscera such as intestinal loops or the urinary bladder. The position of the penis caudal to testicles makes a prescrotal approach with a single incision on the midline possible.[6]

Different techniques have been described for orchiectomy in rabbits: the traditional scrotal approach using a closed or open technique,[6,9] the prescrotal approach,[6] and, as the rabbit is a functional cryptorchid, the abdominal

approach.[6,18] Each technique has practical advantages and disadvantages. The scrotal techniques are well described, most familiar to practitioners, and can be accomplished rapidly. The prescrotal approach, however, is the best technique for proper anatomical closure of the inguinal canals. Due to the position of the penis, manipulation of the delicate skin of the hemiscrotal sacs, including shaving and scrubbing, is completely avoided. In this technique, a 1.5–2 cm incision is made on the midline just cranial to the base of the hemiscrotal sacs. Blunt dissection of the subcutaneous tissue and inguinal fascia reveal the vaginal processes where they lie just before entering the abdomen through the inguinal canal. The vaginal process is bluntly dissected from the surrounding soft tissues and isolated, and 3 to 4-0 suture material passed around it and tied loosely to act as a stay suture. The vaginal process is incised to access the testicle and spermatic cord, which are gently grasped and exteriorized through the incision. The ligament between the hemiscrotal sac and the tail of the epididymis is gently dissected, and the spermatic cord containing blood vessels and nerves is clamped, ligated and removed. Ligation of the testicular blood vessels can be performed separately in larger rabbits, if desired. The preplaced stay suture is tied, which will close the vaginal process. Inguinal fascia and subcutaneous tissue are sutured.

Rodents: male

In general, the testicles of male rodents are large relative to body size, and round in shape.[10,19–21] The epididymis is well developed, both at the caudal and the cranial pole in the rat. The surrounding fat is usually abundant. Some species of squirrel-like rodents such as the prairie dog are true functional cryptorchids, as the testicles descend into the scrotal sacs only during the breeding season. The glans of the penis is well developed, especially in porcupine-like rodents such as guinea pigs and chinchillas.

The external genitalia of the guinea pig are encompassed in a well-developed circumanal skin fold, also called the "perineal sac."[21,22] While this structure resembles an anal orifice, the actual anal orifice is located in the deep caudal part of the anal fold, complicating tasks such as rectal measurement of body temperature. In the deep part of the mucocutaneous area are many sebaceous scent glands (also called "grease glands"), which produce a dense, yellow, creamy and odiferous secretion. This anatomical feature predisposes the male guinea pig to impaction of the anal fold with feces, dry secretion, hay, or other bedding material.

The seminal vesicles of the male guinea pig are well developed, tubular, and long, about 10 cm in length. These structures are located in the caudal portion of the abdomen and may cause momentary confusion as they might be mistaken for uterine horns during laparotomy.[21]

As in rabbits, techniques for castration include open and closed scrotal techniques, the prescrotal approach, and the abdominal approach. The prescrotal technique is effective in rodent species,[19,20] both for access to the testicles and an anatomic closure of the inguinal ring, which is much wider in rodents than in rabbits. As the penis is located cranially to the scrotal sacs, 2 separated parapreputial incision are required.

The abdominal approach for orchiectomy has also been reported in rodent species.[23] This technique is recommended for squirrel-like rodent species like the prairie dog, outside of breeding season, or in very young animals where it may be difficult or impossible to locate the testicles in the scrotal sac.

Rabbits: female

Like cats and ferrets, female rabbits are induced ovulators, with ovulation occurring 10–13 hours after mating. There is no estrus cycle, but rather a period of receptivity occurring every 5–6 days.

In the female rabbit, the ovaries, oviducts, and the uterus are paired organs, similar to the case in other placental mammal species.[10,24] Ovaries are not located in a true ovarian bursa as in some carnivore and rodent species,

but are usually surrounded by fat that also surrounds the mesovarium and the mesosalpinx. The uterus is a complete paired organ (not partially paired as in most of other placental mammal species). It is bicornuate with 2 cervixes, which open directly and separately into an elongated vagina. The mesometrium (broad uterine ligament) is usually filled with fat, especially in overweight or obese rabbits. The vaginal body is a long, large, and flaccid unpaired organ. The urinary bladder is positioned ventrally to the vagina and uterine horns, and the urethra opens into the ventral aspect of the vaginal body. This marks the division between the vestibulum, which is caudal to the urethral opening, and the larger true vaginal body, which is cranial to the urethral opening.[10,24]

Technique for ovariohysterovaginectomy in rabbits is similar to ovariohysterectomy in other species. It may be advantageous to remove as much of the vaginal body as possible, as reflux of urine from the bladder to the vagina is possible, and to prevent infection in the vaginal remnant, similar to "stump pyometra" in other species.

Rodents: female

In rodent species, an alternative development of the primitive urogenital sinus leads the urethra of female animals to open outside the vagina. Therefore, 3 separate openings are present: the urethral, the vaginal, and the anal orifice.[10] Another difference from female rabbits is that female rodents have an unpaired cervical canal, which opens into the vagina through a single cervical opening. In reality, the length of the fused, unpaired tract is different among the rodent species: in porcupine-like rodents such as guinea pigs and chinchillas the cervical canal is easily recognized; in rat-like rodents some authors[25] describe a cervical canal, but 2 separate cervical openings are also reported in the female hamster. Ovariohysterectomy is similar to feline/canine technique in these species, but can be complicated by abdominal fat in older or obese animals, by the more cranial position of the ovaries that are often surrounded by abundant fat in guinea pigs, or by small patient size.

Indications for Surgical Alteration of Carnivores

Indications for reproductive surgery of carnivores include elimination of breeding and reduction of hormonal aggression. Many intact male carnivores have increased musky odor, in particular, the ferret.

Female ferrets are induced ovulators, and estrus cycles begin at about 6–9 months of age. Failure to mate results in unabated estrogen production, ultimately leading to bone marrow suppression and pancytopenia, with resulting non-regenerative anemia.[26] Most female ferrets in the United States are mass-produced by large commercial breeding facilities and spayed prior to arrival at pet stores. However, ferrets from private breeders are occasionally encountered, and the practitioner must educate the owner on the necessity of surgical alteration, or alternatives such as breeding or sham mating with a vasectomized male ferret. Intact female ferrets presented for ovariohysterectomy after the onset of estrus must be evaluated for non-regenerative anemia, and supportive care may be indicated, including blood transfusion.[27]

The testicles of the ferret are similar to those of the cat, while the penis resembles that of the dog.

The body of the penis is not visible, but is easily palpable due to the J-shaped os penis (which lies dorsal to the urethra). The prepuce is the only visible part of the male external genitalia in ferrets that have been neutered prior to puberty, and for this reason it is not unusual for owners to mistake the gender of their male pet. The prostate gland of the ferret is present at the base of the urinary bladder and surrounds the urethra. It is not distinct in neutered males, but enlargement and other diseases can occur due to hormonal stimulation resulting from adrenal gland disease.[28]

The uterine horns of female ferrets are long, and they fuse immediately in front of the cervix, forming a short body.[28] The ovarian bursa is not well developed. The vulva appears as a small slit a few millimeters cranial to the anal orifice. Estrus or hormonal stimulation due to adrenal disease can produce significant enlargement of the vulva. Orchiectomy and ovariohysterectomy of ferrets is straightforward, and surgical technique is similar to that performed in cats.

The reproductive cycle of the spotted skunk (*Spilogale putorius)* is well described, as this species is a common laboratory model for reproductive studies, in particular those involving delayed implantation. Much less information is available on the species most commonly encountered as a pet, the striped skunk (*Mephitis mephitis*), but which is assumed to be similar.[29] However, 2 references claim the striped skunk to be an induced ovulatory, while the spotted skunk is a spontaneous ovulator.[29,30] The skunk is seasonally polyestrus with estrus cycles occurring between September and January. Pet skunk groups commonly claim that intact female skunks are extremely aggressive during estrus, and therefore recommend surgical alteration. Another commonly circulated statement is that intact, unbred female skunks have a high incidence of reproductive tract-related disease and death, and compare the need for surgical alteration to that of the ferret. The author (A. M. L.) has encountered at least 2 owners who claim their intact female skunks do not display aggressive behavior during estrus, and is unable to substantiate claims regarding medical necessity of ovariohysterectomy. However, overwhelming anecdotal reports do indicate surgically altered male and female skunks display less aggression and have better pet quality.

The anatomy of the reproductive tract of skunks is similar to that of dogs, and the surgical technique is the same. The author (A. M. L.) prefers a prescrotal castration technique in male skunks.

Miscellaneous Species

Determining the gender of hedgehogs is not difficult, as the male has a ventral prepuce located in the middle of the abdominal surface. The testicles are not visible due to lack of a true scrotal sac, and because they usually remain within the abdomen. Elective castration is most easily performed through the abdominal approach, as in squirrel-like rodents. Males possess many accessory glands: paired prostate glands, seminal vesicles, bulbourethral glands, and Cowper's-like glands.[32,33]

The vulva appears as a small slit close to and cranial to the anal opening. The reproductive tract of the female is located in the caudal portion of the abdominal cavity. Uterine horns are short, and they open into the long vagina through a single cervix. A fan-shaped paired gland, homologous to the male Cowper's-like glands, lies laterally to the vagina.[33]

Intact hedgehogs are not overtly aggressive, therefore elective surgical alteration is not commonly performed. While overall incidence in pet populations is unknown, mammary neoplasia and neoplasia of the reproductive tract appear to be common in hedgehogs. One study reported an overall incidence of neoplasia of 53% in captive hedgehogs, with the most common sites being mammary tissue, digestive tract, and the endocrine system.[34] Uterine neoplasia is most commonly adenosarcoma, and a common clinical feature is vaginal bleeding.[35] It is unknown whether preventative hysterectomy will reduce the incidence of mammary tumors, or should be considered for prevention of uterine neoplasia, as hedgehogs are prone to neoplasia of many other organ systems as well.

The anatomy of the genital system of swine is extensively described in the literature. The practitioner must keep in mind that the reproductive tract of the female pig is located more caudally than in dogs, and that the ovarian ligament and the uterus itself are more friable than in carnivores.[36,37]

Orchiectomy in pigs is recommended to prevent development of offensive odors and aggressive behavior, typically occurring at puberty, which is typically at 3.5–4 months of age.[38] Surgical technique is pre-scrotal, as performed in dogs. It is not known if potbellied pigs have the same predisposition, but because the domestic pig is genetically predisposed to inguinal hernia, it may be advisable to suture the external inguinal ring.[36,37]

Ovariohysterectomy is performed to prevent aggressive behavior in the sow. When surgery is performed prior to puberty, the uterus is much smaller but less accessible. After puberty, however, a large amount of fat can surround the ovaries and the uterine horns, making surgery more challenging.[36,37]

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