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Surgical methods of contraception and sterilization

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Abstract

Many techniques for surgically sterilizing dogs and cats have been described; each technique offers advantages and disadvantages to both the patient and surgeon. Techniques that have been described include traditional midline ovariohysterectomy, lateral flank ovariohysterectomy, castration, early age gonadectomy, ovariectomy, laparoscopic ovariohysterectomy and ovariectomy, and vasectomy. Regardless of the technique selected, strict adherence to sound surgical technique and asepsis is mandatory for good surgical outcome with minimal complications. This review will discuss surgical principles, complications, outcomes, as well as relevant current literature associated with each of these techniques of surgical sterilization.

Keywords: Ovariohysterectomy; Ovariectomy; Castration; Early age gonadectomy; Vasectomy

1. Introduction

Surgical sterilization of dogs and cats is one of the most commonly performed procedures in veterinary practice, and is done as a method of contraception to aid in the pet overpopulation problem, as well as to prevent diseases associated with the reproductive system, such as mammary neoplasia or benign prostatic hyperplasia [1–3]. Many surgical sterilization techniques have been described, including traditional midline ovariohysterectomy, lateral flank ovariohysterectomy, castration, early age gonadectomy, ovariectomy, laparoscopic ovariohysterectomy and ovariectomy, and vasectomy. This review will discuss surgical principles, complications, outcomes, as well as relevant current literature associated with each technique.

2. Traditional midline ovariohysterectomy

In dogs and cats, ovariohysterectomy is traditionally performed through a small ventral midline incision. In adult female dogs, the incision typically begins at, or not more than 1 cm caudal to, the umbilicus [4]. In cats, however, the incision is centered in the middle third of the distance between the umbilicus and the pubis so as to enable easier access the uterine body and cervix [4]. The length of the incision should be such that it is possible to readily expose the ovaries as well as the junction of the cervix and uterine body, for easy ligature placement. Once the reproductive tract has been identified, the suspensory ligament should be carefully broken using caudolateral or caudomedial traction on the suspensory ligament with the index finger of the dominant hand, while holding traction on the proper ligament using the nondominant hand.

Several techniques have been described for clamping and ligating the ovarian and uterine pedicles, including the single-, double-, and triple-clamp methods. Regardless of the technique selected, it is important to either

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visualize the ovary (in cats), or carefully palpate the ovary (in dogs the ovary is ''hidden'' in ovarian bursal fat) between the thumb and index finger, and then to ''pinch'' the thumb and forefinger together (while holding and protecting the ovarian tissue) deep to the ovary prior to placement of the clamp. This will prevent inadvertent clamping of the ovarian tissue, which could result in ovarian remnant tissue syndrome. The double- and triple-clamp methods are particularly useful if pyometra is present [4], whereas the single-clamp method is preferred with small, friable, or fragile reproductive tracts [5,6]. Double ligations, utilizing an encircling and a transfixing ligature (or two transfixing ligatures) are recommended on all ovarian pedicles in adult dogs, whereas double encircling ligatures may be sufficient in adult cats, unless the cat is pregnant or in estrus.

When ligating the uterine body, it is important to place the most caudal ligature at the junction of the cervix and uterine body, so as to avoid leaving any viable uterine body tissue that could result in a stump pyometra in the future [4]. The second ligature is placed cranial to the first ligature, and is appropriately spaced so as to avoid leaving excessive devitalized tissue.

2.1. Complications of ovariohysterectomy

Complications associated with ovariohysterectomy often result from inappropriate technique while performing the procedure, and are easily prevented by being attentive to good surgical technique. Complications that have been reported secondary to ovariohysterectomy in the dog and cat include hemorrhage, ovarian remnant syndrome, stump pyometra, stump granuloma, fistulous draining tracts, eunuchoid syndrome, accidental ureteral ligation, and estrogen-responsive urinary incontinence [4,7–21].

Hemorrhage is one of the most common complications secondary to an ovariohysterectomy, and can result in death of the patient if severe [4]. Hemorrhage is also a readily preventable complication of ovariohysterectomy. Hemorrhage can occur from the ovarian pedicle, uterine pedicle, or from the broad ligament. Use of careful technique while breaking the suspensory ligament, handling and manipulating the ovarian and uterine pedicles, and placing ligatures is important in preventing hemorrhage. Ensuring proper placement, spacing, and tightness of ligatures is also critical in preventing intraoperative and postoperative hemorrhage. Careful examination of each pedicle with tension relieved, prior to release of the pedicle, is an important step in preventing hemorrhage in the ovariohysterectomy patient. Ligation of the broad ligament may be necessary, particularly in the patient that is in estrus at the time of the ovariohysterectomy. Lastly, it is good technique to always perform a ''final hemorrhage check'' in which the abdomen and pedicles are examined for any evidence of hemorrhage prior to closing the abdominal cavity. If hemorrhage is identified at any time during the procedure, it is important to determine the source of hemorrhage and achieve hemostasis through appropriate exposure and additional ligations.

Ovarian remnant syndrome is the presence of functional ovarian tissue in the abdomen following ovariohysterectomy that may result in signs of proestrus, estrus, and (rarely) false pregnancy due to the production of estrogen and progesterone [8–12]. Ovarian remnant syndrome may be seen in both dogs and cats following routine ovariohysterectomy in which all ovarian tissue is not removed due to inappropriate ovariohysterectomy technique. Techniques that may predispose to ovarian remnant syndrome include inadequate exposure of the ovarian pedicles resulting in poor visualization, inaccurate placement of clamps or ligatures, or accidental separation of a portion of the ovary with subsequent loss of the tissue in the abdomen (not a likely cause as most ovarian remnants are found at the ovarian pedicle). Vaginal cytology during proestrus or estrus demonstrating cornification of vaginal epithelial cells is the easiest (and least expensive) method to diagnose ovarian remnant syndrome in dogs [10]. Resting serum estradiol concentrations may be measured, but timing and interpretation are critical when using single samples [10]. Serum progesterone assays may be more useful (in bitches) than estradiol assays [10]. Surgical exploration and excision of remnant tissue via exploratory laparotomy is the treatment of choice [4]. Timing of surgery should be delayed until the animal is in estrus to permit easier identification of the remnant tissue, and all excised tissue should be submitted for histologic confirmation that ovarian tissue has been removed [4]. Any suspicious tissue should be removed using care to identify and preserve the ureters, and the uterine pedicle should be examined for complete removal. Upon removal of the remnant ovarian tissue, clinical signs should resolve within days [10].

Stump pyometra may occur following ovariohysterectomy if a portion of the uterine horns or uterine body is not removed and the animal has increased progesterone concentrations [4,9,13]. The increased serum progesterone occurs from either residual ovarian tissue (endogenous source), progestational compounds used to

treat dermatitis (exogenous source), or potentially absorbed from progestins found in creams used for treatment of menopausal symptoms in women (exogenous source) [4]. Stump granuloma and inflammation may be caused by excessive residual devitalized uterine body tissue, use of inappropriate nonabsorbable suture material or cable ties, or poor surgical asepsis [4,13,14]. Stump granulomas may result in adhesions that interfere with urinary bladder sphincter function and result in mechanical urinary incontinence after ovariohysterectomy [13,14]. Affected tissue associated with a stump pyometra or a stump granuloma must be surgically removed (using care to avoid ureteral damage) to achieve resolution of the problem.

In addition to stump granulomas, inflammatory response to ligature material (often nonabsorbable, braided suture material or cable ties) may result in fistulous draining tracts [9]. These draining tracts may extend from the offending material through the muscle planes to the skin, resulting in soft, painful swellings beneath the skin in the flank region, inguinal region, precrural fold, or medial thigh [4]. Purulent material or blood-tinged fluid may drain intermittently, and may be temporarily resolved by antimicrobial administration, but quickly recurs after antibiotics are discontinued. Treatment involves exploratory laparotomy, and careful removal of all offending tissue and foreign material, using care to preserve the ureters.

Eunuchoid syndrome is a condition reported in female dogs, particularly working females, in which ovariohysterectomy results in a diminished ‘‘drive’’ (or ‘‘aggression’’) and stamina [7]. Ovarian autotransplantation has been described as a technique to prevent or minimize the clinical signs associated with eunuchoid syndrome in these dogs [15,16]. The technique involves autotransplantation (performed at the time of ovariohysterectomy) of ovarian tissue into ‘‘pockets’’ created in the seromuscular layer of the greater curvature of the stomach [15,16]. Since the stomach is drained by the portal system, the transplanted ovary is suggested to produce hormones that are delivered to the portal system (rather than systemic circulation) resulting in hormonal levels sufficient to prevent eunuchoid syndrome, but at insufficient levels to result in overt clinical estrus. However, a retrospective study of 66 dogs that had undergone autotransplantation of ovarian tissue at least 5 y earlier reported that 14% of dogs developed signs of estrus [16]. Additionally, 20% of the dogs also developed urinary incontinence. Ovarian autotransplantion should be avoided because of the high rate of complications and lack of efficacy.

Accidental ligation of a ureter, which can result in hydronephrosis or atrophy of the kidney, is easily preventable by careful identification of the uterine horns, uterine body, and cervix prior to ligation of the uterine body, and avoidance of ligation of any extraneous peribladder fat which may contain a ureter [17,18]. Ureteral ligation is more likely when a distended urinary bladder is present because the trigone and ureterovesical junction are moved cranially and the ureters contain more slack, enabling ureteral entrapment in ligatures [4].

Estrogen-responsive urinary incontinence, or urinary sphincter incontinence, after ovariohysterectomy or ovariectomy, can occur immediately after surgery or as long as 12 y after surgery, with an average onset of almost 3 y [19]. It has been reported to occur in as many as 11–20% of dogs undergoing ovariohysterectomy or ovariectomy [19]. Small breed dogs appear to be at low risk, whereas large and giant breeds appear to be at high risk [19]. Medical management of estrogen-responsive urinary incontinence includes phenylpropanolamine, diethylstilbestrol, or imipramine [4,20]. Colposuspension may be tried in dogs with a pelvic bladder that are nonresponsive to medical management [21]. Colposuspension, which involves placement of sutures between the cranial vagina and prepubic tendon to return the neck of the bladder and proximal urethra to an intraabdominal location, is curative in approximately 50% of animals treated, with most of the remainder showing substantial improvement [21].

3. Lateral flank approach for ovariohysterectomy

An alternative to the conventional ventral midline ovariohysterectomy is the lateral flank approach [22–26]. The lateral flank approach has been suggested as an acceptable approach where an animal has excessive mammary development or in situations, such as feral cat ovariohysterectomy, in which postoperative monitoring and examination may be limited [22,24]. The principle advantage that has been cited for the lateral approach is the decreased likelihood of evisceration should the body wall dehiscence occur after surgery, whereas the principle disadvantage sited is the limited exposure of the contralateral side, particularly in the event of complication [22]. Other disadvantages include difficulty identifying a previous ovariohysterectomy incision scar, and possible imperfections in hair color of growth patterns on the flank [22]. Contraindications for performing the flank approach include pregnancy, pyometra, estrus, obesity, and age $<$12 wk [22].

The lateral flank approach is used more commonly in cats because of their consistent body conformation, narrow abdominal width, and the thin, pliable musculature of the flank region [22]. In dogs, the lateral approach is easier to perform in small dogs or dogs with a narrow body conformation [22]. The approach should be avoided in dogs that have a wide body conformation or thick trunk musculature.

When performing the lateral flank approach, animals may be placed in either left or right lateral recumbency. Some surgeons prefer the right flank approach because it is easier to access the more cranially located right ovary, and because the omentum covers the viscera when approached from the left [22]. The lateral approach is performed through a dorsoventral incision that is placed just caudal to the midpoint between the last rib and iliac crest [22]. In cats, the incision length is approximately 2 cm, and approximately 3 cm in dogs, but can vary depending upon the size of the animal. The abdominal wall is entered via a grid approach using blunt dissection through the separate layers of muscle. Once the uterus and ovary have been identified, the ovarian pedicle is isolated and ligated in standard fashion. After the ovarian pedicle is ligated, and the broad ligament to that side is torn, the uterine horn is traced to the bifurcation, and the second uterine horn identified and traced cranially to the second ovary. Visualizing the contralateral ovarian pedicle can be difficult through a small flank incision, and it may be necessary to enlarge the incision. Once the second ovarian pedicle has been ligated, and the broad ligament divided, traction is applied to both uterine horns to expose the ligation site on the uterine body. The uterus is then ligated in standard fashion. After verifying lack of hemorrhage, the body wall musculature of cats can be closed as a single layer. In dogs, however, the musculature should be closed in two layers [22]. Subcutaneous tissue and skin closure is routine.

4. Castration

In the dog, canine castration may be performed by either an open or closed technique, in which the testis is displaced cranially and exposed using a midline prescrotal skin incision [27]. Since the male dog is considered to be ''scrotal conscious'', the scrotum itself should not be clipped or prepped, and the scrotum should be draped out of the surgical field so as to avoid self-mutilation postoperatively. The open technique is preferred in larger dogs since ligatures may be placed directly around the vascular pedicle, resulting in more secure ligations [27]. The advantages of the closed technique are that the technique is simpler to perform, and the parietal vaginal tunic has not been opened, thereby minimizing risk of peritoneal contamination via the communication between the abdomen and the parietal vaginal tunic [27]. Disadvantage of the closed technique involves less secure ligatures because the vessels are ligated while being surrounded by the tunic and the attached cremaster muscle, rather than being ligated directly [27].

Cats may also be castrated via an open or closed approach, with the closed technique generally preferred because of the inability to create and maintain a high degree of surgical asepsis in the male cat. The spermatic cord may be ligated using suture material, or preferably, may be ligated using the spermatic cord itself by placing an overhand knot in the cord (avoids placement of exogenous foreign materials into a potentially contaminated environment) [27,28].

Complications of castration include scrotal swelling, hemorrhage, bruising, and infection. In the dog, swelling and bruising of the scrotum are more commonly seen after open castration [29]. Hemorrhage after castration may be serious, and may result in scrotal hematoma or intraabdominal hemorrhage [27]. Serious hemorrhage may require intensive supportive care and an abdominal approach to locate and ligate the spermatic cord [27]. Scrotal hematoma, if severe, may necessitate scrotal ablation.

5. Early-age gonadectomy

Pediatric ovariohysterectomy may be performed similarly to adult ovariohysterectomy with some slight modifications [30–32]. Generally, the uterus is more easily exposed in puppies if the incision is started relatively more caudal to the umbilicus than adult dogs (at least 2–3 cm caudal to the umbilicus) resulting in the incision positioned at, or near, the middle third of the distance from the umbilicus to the pubis, similar to a feline incision. In kittens, the incision is placed in a similar location as in an adult cat. Upon entrance into the abdomen, it is common to encounter substantial amounts of serous fluid in both puppies and kittens, which may need to be removed using gauze sponges to improve visualization. The use of a Snook ovariohysterectomy hook should be avoided in pediatric patients due to the delicate nature of the tissues. Because of incision location in both puppies and kittens, the uterus is easy to locate by retracting the bladder and looking between the urinary bladder and colon. Uterine tissues are extremely small and friable in young puppies and kittens, therefore care must be taken to avoid excess

traction and tearing of tissues. After the uterus has been located, the procedure may be performed similarly to the adult OHE, using care when breaking the suspensory ligament and ligating the fragile pedicles. Although the triple-clamp method may be used in pediatric OHE, it is often difficult to place clamps appropriately without tearing tissues, and proves cumbersome. Closure is routine, however, it is important to carefully identify the ventral fascia (external rectus sheath) and differentiate it from the overlying subcutaneous tissue since they can occasionally be difficult to distinguish (particularly in some puppies). The subcuticular layer may be closed with an absorbable suture material in a continuous intradermal pattern to avoid the use of skin sutures. Alternatively, skin sutures may be loosely placed following closure of the subcutaneous tissues.

Pediatric puppy castration is also performed with modifications to the techniques used in adult dogs [30–32]. Because puppy testes are mobile and can be difficult to identify, careful palpation must be used to determine whether both testes have descended into the scrotal region before beginning surgery. If one or both testes have not descended, standard cryptorchidectomy techniques may be used for castration. The entire scrotal region is clipped and surgically prepared to permit the scrotum to be incorporated in the surgical sterile field, so as to facilitate location and manipulation of the testes during surgery. Clipping and surgical preparation of the scrotum does not result in scrotal irritation in puppies as it does in adult dogs because the scrotal sac of puppies is not well developed as compared to adult male dogs. Puppies may be castrated through a single midline (preferred) prescrotal or scrotal incision, or through two scrotal incisions positioned similarly to a feline castration. When a midline incision is used, the testes must be securely held underneath the incision site to prevent iatrogenic penile trauma. Following exposure of the testicle and spermatic cord in closed fashion (testes remain enclosed in the parietal vaginal tunic during castration), the spermatic cord is ligated (double ligations preferred) with absorbable suture material or stainless steel hemostatic clips. Should the parietal vaginal tunic be inadvertently penetrated and the testis extruded, an open castration technique may be performed using standard adult canine castration techniques. Incisions may be closed using one or two buried interrupted sutures in the subcuticular layer, or incisions may be left open to heal by second-intention healing. Closure of the incision prevents postoperative contamination with urine or feces, and prevents extrusion of fat from the incision.

Kitten castration is performed using identical techniques as in the adult cat, including the use of two separate scrotal incisions to approach the testes [30–32]. As with the pediatric puppy, the testes of the pediatric cat are extremely small, highly mobile, and occasionally difficult to stabilize in the scrotal region in preparation for incision. The testis should be securely stabilized in the scrotal region and the incision made directly over the testis at the ventral most aspect of the scrotal ''sac''. After the incision, the testis is careful exposed using gentle caudoventral traction. It is important to realize that the pediatric testis cannot be exteriorized to the same distance as the adult cat without potential tearing of the spermatic cord. The closed castration technique is preferred, using a hemostat to place an overhand throw in the pedicle, or using suture or hemostatic clips for hemostasis. If the parietal vaginal tunic is inadvertently opened, an open technique using a either a hemostat to place an overhand throw in the spermatic cord, or the use of spermatic cord tissues for knot tying may be employed. Alternatively, sutures or hemostatic clips may be used to achieve hemostasis in an open castration.

To prevent unnecessary abdominal exploratory surgery in the future, all animals undergoing early-age ovariohysterectomy should be tattooed to identify their neutered status. The recommended tattoo site is the prepubic area in females. The female gender symbol along with an encircled ''X'' is used to denote the neutered status. Tattooing may be performed after the surgical site has been clipped but prior to the surgical prep of the area.

5.1. Outcome–risks versus benefits

Although the anesthetic and surgical procedures for early-age gonadectomy have generally been reported as safe, veterinarians have remained concerned about long-term health risks including infectious diseases and immune suppression, long bone growth, urethral development in cats, estrogen-responsive urinary incontinence in dogs, and obesity. Since the 1990′s, there has been a proliferation of information in the literature assessing the long-term health risks and benefits of early-age ovariohysterectomy as compared to traditional-age gonadectomy.

In some short-term studies conducted at animal shelters, puppies and kittens neutered at early ages had no higher risk of infectious diseases than older animals. One study involved dogs and cats from two animal shelters undergoing gonadectomy surgeries in association with the fourth-year student surgical teaching

program of a university teaching hospital [31]. Twelve of 1988 (0.6%) animals died or were euthanized because of severe infections of the respiratory tract or as the result of parvovirus infection during the 7 d postoperative period, and the deaths (or euthanasias) included similar numbers of animals from all age groups.

In a long-term study of 263 cats (36 mo median follow-up), prepubertal gonadectomy did not result in an increased incidence of infectious diseases after adoption in cats, compared with traditional age gonadectomy [33]. A more recent studies of 1660 cat (47 mo median follow-up) demonstrated that those gonadectomized before 5.5 mo of age were no more likely than those gonadectomized after 5.5 mo of age to have any conditions that were apparently associated with long-term immune suppression [34]. It was noteworthy that early-age gonadectomized cats had a lower incidence of gingivitis, a condition that may be associated with immune suppression.

In dogs, a long-term study of 269 dogs (48 mo median follow-up) demonstrated that gonadectomy before 5.5 mo of age was associated with increased incidence of parvoviral enteritis [35]. A more recent study of 1842 dogs (54 mo median follow-up) also showed that, on a short-term basis, dogs that were gonadectomized at an early age had an increased incidence of parvoviral enteritis that often occurred soon after adoption [36]. In both of the long-term dog studies (269 dogs and 1842 dogs), the increased incidence of parvoviral enteritis on a short-term basis probably represented an increased susceptibility of the younger puppies during the periadoption period, rather than long-term suppression.

In a 15-mo study, the effects of prepubertal gonadectomy on skeletal growth, weight gain, food intake, body fat, and secondary sex characteristics were investigated in 32 mixed-breed dogs neutered at 7 wk, 7 mo, or left intact [37]. Although growth rates were unaffected by gonadectomy, the growth period and final radial/ulnar length was extended in bitches neutered at 7 wk of age. Thus, rather than being ‘‘stunted’’ in growth, they were actually slightly (as determined by radiographs) taller. In a similar study, 31 cats were neutered at 7 wk or 7 mo or left intact [38]. Distal radial physeal closure was delayed in gonadectomized cats when compared to intact cats; however, no differences were detected between cats neutered at 7 wk or 7 mo for mature radius length or time of distal radial physeal closure.

The clinical significance of delayed closure of growth plates is not clear, but it does not appear to render the growth plates more susceptible to injury. In the long-term studies of 263 cats and 269 dogs, no differences in the incidence of musculoskeletal problems were seen between animals neutered at a traditional age or at an early age [33,35]. Further, in the long-term studies of 1660 cats and 1842 dogs, age at gonadectomy was not associated with the frequency of long bone fractures [34,36]. In all these studies, long bone fractures were rare overall, suggesting that physeal fractures are not a common problem in gonadectomized dogs and cats in general.

Long-term studies have examined the incidence of hip dysplasia in dogs and the association with age at gonadectomy. Although the study of 269 dogs found no association between age at gonadectomy and hip dysplasia, the study of 1842 dogs found that early-age gonadectomy was associated with a significant increased incidence of hip dysplasia [36]. Puppies that underwent gonadectomy before 5.5 mo of age had a 6.7% incidence of hip dysplasia, whereas those that underwent gonadectomy at the more traditional age had an incidence of 4.7%. However, those that were gonadectomized at the traditional age were three times more likely to be euthanized for the condition as compared to the early-age group; the authors suggested that early-age gonadectomy may be associated with a less severe form of hip dysplasia.

Although many veterinarians are concerned that of feline lower urinary tract disease (FLUTD) and urethral obstruction in male cats may occur secondary to early-age neutering, there have been numerous experimental and clinical studies dating to the 1960′s examining this issue. More recently, two experimental studies examining cats castrated at 7 wk and 7 mo of age as compared to sexually intact cats have addressed this concern [39,40]. The first study examined urethral development when cats were 1 y of age, and found that urethral diameters as determined by contrast retrograde urethrography were similar among both groups of neutered cats as compared to intact cats [39]. Additionally, there was no difference among groups in urethral dynamic function as determined by urethral pressure profiles. Voiding cystograms were used to measure the diameter of the preprostatic and penile urethra when cats were 22 mo of age in the second study, which also found no differences in urethral diameter of male cats neutered at 7 wk or 7 mo of age as compared to intact cats [40].

In addition to experimental studies, two recent long-term clinical studies have examined the effect of early-age castration on the incidence of urinary tract disease. The first long-term (37 mo median follow-up) study examined 263 cats neutered at an early age (<5.5 mo)

as compared to the traditional age of ≥5.5 mo [33]. There were 108 male cats that were castrated at an early age (median age at castration = 9 wk; $n = 70$) or at the more traditional age (median age at castration = 51 wk; $n = 38$). In that study, traditional-age cats had significantly more overall urinary tract problems (17%) as compared to early age cats (3%), with ''cystitis'' being the most common problem seen, and with a significantly greater incidence in traditional-age cats. There was no significant difference in the rate of urethral obstruction between groups, although two of 38 (5%) traditional age cats suffered urinary obstruction, whereas zero of 70 (0%) early-age cats became obstructed. A second recent study examined 1660 cats (median follow up of 47 mo) neutered at an early age (<5.5 mo of age) as compared to the traditional age (≥5.5 mo of age) [34]. That study found no association between the incidence of FLUTD or urethral obstruction and age at gonadectomy.

In addition to urethral development, genitalia development in male cats castrated early has also been a concern for many veterinarians. The balanopreputial fold is a continuous layer of epithelium that forms a fold of tissue connecting the penis to the prepuce at birth [41]. The separation process for this fold of tissue is androgen-dependent and is complete at birth in some species, but not until after puberty in other species such as the cat [41]. It has been suggested that prepubertal castration in cats might delay or prevent dissolution of the membrane, and predispose to ascending urinary tract disease, since these cats may not be able to fully extrude the penis for cleaning [41]. Recent studies examining separation of the balanopreputial fold have reported conflicting results. In one study of cats castrated at 7 wk and 7 mo of age, it was reported that at 1 y of age, the penis could be fully extruded in all males [38]. This was in direct contrast to another study reporting on penile extrusion in cats at 22 mo of age [40]. Of the cats neutered at 7 wk of age, the penis could be fully extruded in none of the cats, whereas in intact cats, the penis could be fully extruded in all of the cats. Of the cats neutered at 7 mo of age, the penis could be fully extruded in 60%. It would appear, however, based upon the long-term clinical studies of 263 and 1660 cats, that failure of separation of the balanopreputial fold (when present) does not cause a clinical problem in cats neutered early and does not lead to an increase in the incidence of FLUTD or urinary obstruction [33,34]. Should cats become obstructed, however, catheterization may be more challenging because of potential inability to fully extrude the penis and small penile size.

The incidence of estrogen-responsive urinary incontinence is increased among neutered female dogs, and concerns have been raised that gonadectomizing puppies at an earlier age might further increase the risk for spayed bitches. The long-term study that evaluated 269 dogs adopted from shelters and neutered at <5.5 mo of age, or at ≥5.5 mo of age, found only three cases where owners reported urinary incontinence [35]. One dog was neutered at an early age and two dogs were neutered at the traditional age. In contrast, however, the long-term study of 1842 dogs found that decreasing age at the time of ovariohysterectomy was associated with increasing incidence of urinary incontinence that required medical treatment [36]. Puppies that underwent ovariohysterectomy before 3 mo of age appeared to be at the greatest risk. The authors of this study recommend that female puppies should not undergo ovariohysterectomy until at least 3–4 mo of age. The authors note, however, that in certain shelter environments, the need for gonadectomy prior to adoption may outweigh the risk of urinary incontinence.

Although obesity can occur in both neutered and intact animals, and is influenced by a number of factors such as diet and activity level, data suggests that neutered cats may gain significantly more weight than those remaining intact. When comparing sterilized cats to sexually intact cats, intact cats were found to weigh less than cats altered at 7 mo, but there was no difference between intact cats and those neutered at 7 wk [38]. A second study of 36 cats gonadectomized at 7 wk, 7 mo, or left intact demonstrated that the heat coefficient, a measure of resting metabolic rate, was higher in intact cats than in gonadectomized cats [42]. Therefore, animals gonadectomized at either age were more likely to be obese than intact cats. Based on these data, the author suggested that neutered female cats require an intake of 33% fewer calories than intact female cats [42]. Another study confirmed these findings, and demonstrated that the maintenance energy requirement was substantially lower for spayed female cats than for sexually intact cats [43].

The information on whether dogs are more likely to experience weight gain following ovariohysterectomy is less clear. In a retrospective study in which information on body condition was gathered on over 8000 dogs from 11 veterinary practices in the United Kingdom during a 6-mo survey, spayed dogs were about twice as likely to be obese as intact female dogs [44]. However, a different study found no differences in food intake, weight gains, or back-fat depth among neutered (7 wk or 7 mo) and

intact animals during a 15 mo prospective study [37]. In contrast, the long-term study of 1842 dogs actually found that the proportion of overweight dogs was lowest in the early-age gonadectomized dogs, as compared to the traditional age dogs [36].

6. Ovariectomy

Although the technique has never become popular in the United States, bilateral ovariectomy has been described as an alternate to traditional ovariohysterectomy [23,45]. Bilateral ovariectomy has been proposed as being preferred over ovariohysterectomy because of smaller incisions and decreased abdominal trauma, and decreased surgery and anesthesia times [45]. The technique is performed using a ventral midline abdominal approach that starts at the umbilicus and extends caudally. The ovary is identified and the ovarian pedicle is ligated using traditional techniques and materials. Once ligated, the ovarian pedicle is severed. The uterine artery and vein are then ligated and severed at the proper ligament (cranial tip of the uterine horn), and the ovary removed. Closure is routine.

One long-term study examined the effects of ovariectomy and ovariohysterectomy in 135 bitches (69 ovariectomy dogs and 66 ovariohysterectomy dogs) that had undergone neutering 8–11 y previously [45]. With the exception of urinary incontinence, no problems were reported that could be related to the surgical procedure. Six of the ovariectomy dogs and nine of the ovariohysterectomy dogs eventually developed urinary incontinence. Based on the results of that study, the authors concluded that there was no indication for removing the uterus during routine neutering of healthy bitches, and suggested that ovariectomy should be considered the procedure of choice. It is important to recognize that dogs or cats that have undergone ovariectomy could develop the cystic endometrial hyperplasia-pyometra complex should they ever come under the influence of progestins. However, this concern was not supported by results of another report on ovariectomy in 72 bitches, in which no cases of pyometra were identified during the 6–10 y follow-up period [23].

7. Laparoscopic ovariohysterectomy and ovariectomy

The use of minimally invasive surgery has been described as an alternative to traditional surgical midline or flank ovariohysterectomy or ovariectomy [46–50]. As minimally invasive surgery in humans has improved and become more routine and widespread, and as awareness of these techniques has increased in the general population, pet owners are coming to expect that minimally invasive surgery is an option for their pets undergoing various surgeries. Although still uncommon, some surgical specialists are beginning to offer minimally invasive ovariohysterectomy as an option for clients interested in the procedure for their pet. Techniques and equipment to improve surgical efficiency during laparoscopic ovariohysterectomy have been described, and include the use of premanufactured suture loops, the use of the harmonic scalpel in place of ligations, and the use of monopolar or bipolar electrocoagulation for hemostasis.

Laparoscopic ovariohysterectomy has been compared with traditional ovariohysterectomy in dogs in a study in which 16 female dogs underwent laparoscopic ovariohysterectomy that was performed by ligation of the uterus and ovaries, and then removal of the reproductive tract using an assisted laparoscopic technique [47]. These dogs were compared to 18 dogs undergoing traditional ventral midline ovariohysterectomy. Surgical time, complications, and pain scores were evaluated. In that study laparoscopic ovariohysterectomy was performed successfully, but surgical times and complication rates were higher than those of tradition ovariohysterectomy. However, postoperative pain scores were less than the traditional ovariohysterectomy. The authors noted, however, that equipment cost and the necessity for more than one surgeon may limit the technique's usefulness in small animal practice.

The harmonic scalpel has been used as a tool to simplify laparoscopic ovariohysterectomy by negating the need for ligatures [46]. This technology uses ultrasonic energy (no electricity passes through the patient) for precise cutting and controlled coagulation resulting in hemostasis with minimal thermal tissue damage. One study compared postoperative pain after ovariohysterectomy by harmonic scalpel-assisted laparoscopy as compared to traditional midline ovariohysterectomy in 16 dogs that were equally divided into two groups [46]. In that study, the harmonic-assisted laparoscopic technique took significantly longer than the traditional technique. There were no significant differences observed between the two groups for measures of heart or respiratory rates, temperature, creatine phosphokinase, or glucose concentrations. However, the traditional midline ovariohysterectomy group had higher mean plasma cortisol levels 2 h after surgery, and higher mean pain scores at all postoperative times, than did the harmonic scalpel-assisted laparoscopy technique. The authors concluded that the harmonic scalpel-assisted laparoscopic technique was a

safe alternative to traditional ovariohysterectomy (although expensive!).

Laparoscopic ovariectomy has also been described, and the use of monopolar and bipolar electrocoagulation were compared in 103 female dogs in a prospective, nonrandomized clinical trial [50]. That study found that bipolar electrocoagulation decreased laparoscopic ovariectomy time, decreased intraoperative hemorrhage, and facilitated exteriorization of the ovaries, as compared to monopolar electrocoagulation laparoscopic ovariohysterectomy. In that study, bipolar electocoagulation laparoscopy times were 41 min, compared with 53 min for monopolar electrocoagulation laparoscopy. A single surgeon performed all procedures.

8. Vasectomy

Surgical vasectomy involves bilateral removal or occlusion of the portion of the ductus deferens, rendering the animal infertile by preventing sperm from being ejaculated during copulation [51,52]. However, undesirable male sex characteristics and behaviors, as well as androgen-dependent diseases, are not prevented, since androgens are still produced [51]. Vasectomy of dominant males has been suggested as a method of feral cat population control since vasectomized dominant tom cats will prevent submissive, intact toms from inseminating non-spayed females [53].

In both the dog and the cat, vasectomy may be performed through a 1- to 2-cm incision located in the inguinal areas of the dog and cranial to the scrotum (genitalia) in cats [51,52]. Following skin and subcutaneous incision, the spermatic cords are identified, separated, and exteriorized from the tunic using a combination of blunt and sharp dissection. Gentle caudal traction and manipulation of the testicle can be helpful in identifying the spermatic cord and ductus deferens. Following isolation of the ductus deferens, a segment of the ductus is then removed and both of the severed ends of the ductus ligated. It has also been reported that vasectomy may be performed intraabdominally via laparoscopy with occlusion of a segment of ductus using bipolar forceps and electrocoagulation [54]. Vasectomy in the dog has also been described using a Vasocclude clip applying device through a small scrotal puncture site [55]. In this study, 99.9% of sperm were absent within 1 d after vas occlusion. Other studies have reported azoospermia in the dog following bilateral vasectomy to develop from 2 to 21 d, whereas in cats, live sperm have been identified for up to 49 d following prescrotal vasectomy [54–58].

9. Summary

Despite efforts in recent years to identify reliable methods of pharmacologic and chemical sterilization for dogs and cats, surgical methods have remained the mainstay. Although these procedures are often viewed as ‘‘routine’’ surgeries, complications may result from inappropriate techniques, and efforts should be made to follow good surgical and aseptic standards to avoid these complications.

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