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Reproductive Emergencies

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Reproductive problems often arise after normal business hours, so it is not uncommon for them to fall into the domain of the emergency veterinarian. Because most owners lack medical knowledge, they frequently look to the veterinarian to answer questions and to identify potential problems. The emergency clinician must therefore be familiar with normal reproductive behavior in addition to the common emergencies that may arise. With this goal, the events surrounding normal parturition as well as the common complications that may develop during this period are reviewed in this article.

Normal parturition

Normal gestation length in the dog may range from 57 to 72 days from the time of first breeding, with an average length of 65 days [1]. The reason for this apparent variability is that female dogs may stand to be bred as early as 11 days before and as late as 3 days after ovulation [2]. Additionally, canine sperm may survive for 6 to 11 days [1,3] in the female reproductive tract. Thus, there may be considerable variation between the breeding dates and the actual time of fertilization. If the date of the preovulatory luteinizing hormone (LH) peak is known, gestation length becomes less variable, ranging from 64 to 66 days [1]. Because cats are induced ovulators, there is generally less variability in gestation length, which ranges from 63 to 65 days. Ovulation may not take place after the first breeding, however, so in the event of multiple breedings, uncertainties with regard to gestation length may still be present.

As the whelping date approaches, a number of clues may point toward impending parturition. Mammary development, vulvar enlargement, mucous vaginal discharge, and relaxation of the pelvic ligaments are early signs of approaching parturition. Onset of lactation may be noted in primiparous

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bitches within 24 hours of parturition but may occur several days before parturition in multiparous bitches. A sudden drop in body temperature (>2°F) is generally noted within 24 hours of parturition [4] in dogs and cats as a result of decreases in progesterone levels, but this finding is not always reliable. In one recent study, nadir temperature occurred longer than 48 hours before parturition in 24% of dogs and an appreciable drop in temperature (>1°F) was not seen in 35% of dogs [5]. Because the drop in temperature may be transient, twice-daily monitoring is required. Serum progesterone levels typically decrease to less than 2 ng/mL within 24 to 48 hours of parturition [3,6] and thus may be used to predict parturition. Progesterone assays are also useful in confirming the presence of primary uterine inertia in bitches at risk and in deciding that a planned cesarian section may proceed safely.

Maturation of the fetal pituitary-adrenal axis and release of corticotropin are believed to be the initiating events for parturition [3,7]. Release of cortisol from the fetal adrenal glands leads to synthesis and release of prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$) in the placenta and uterus. $PGF_{2\alpha}$ causes regression of the corpus luteum and a sudden drop in progesterone levels. With a decrease in progesterone levels, inhibition of myometrial contractions is removed, leading to uterine contractions, placental separation, and progressive dilation of the cervix.

Normal parturition proceeds in three stages. The first stage is characterized by subclinical uterine contractions and progressive dilation of the cervix. During this stage, which typically lasts for 6 to 12 hours, bitches may show signs of restlessness, apprehension, panting, nesting behaviors, hiding, and anorexia. Queens may be tachypneic, restless, and vocal or may lie purring in their nesting boxes. Active expulsion of the fetuses occurs during the second stage of labor. As the fetuses are forced into the birth canal, mechanoreceptors in the female reproductive tract generate afferent signals (Ferguson's reflex) that result in increased release of oxytocin from the posterior pituitary, thereby increasing the intensity of uterine contractions. The presence of a fetus in the cervix also induces reflex abdominal contractions that aid in parturition. The first fetus is usually delivered within 1 hour of the onset of stage 2 labor in cats and within 4 hours in dogs, with subsequent deliveries every 15 minutes to 3 hours [7,8]. Active straining generally results in expulsion of a fetus within 15 minutes. The entire process generally occurs over 2 to 12 hours but may take as long as 24 hours with large litter sizes in the dog. Normal parturition lengths of up to 42 hours have been reported in the cat [9], but clinical experience urges caution in dismissing these cases without careful evaluation for fetal distress (Fig. 1). The third stage of labor results in expulsion of the placenta. One placenta should be identified for each fetus delivered. Placentas are usually still attached to the fetus by the umbilical cord and emerge with the fetus but may emerge within 15 minutes to several hours if they become detached. Because fetuses are delivered from uterine horns alternately, it is not uncommon to have two

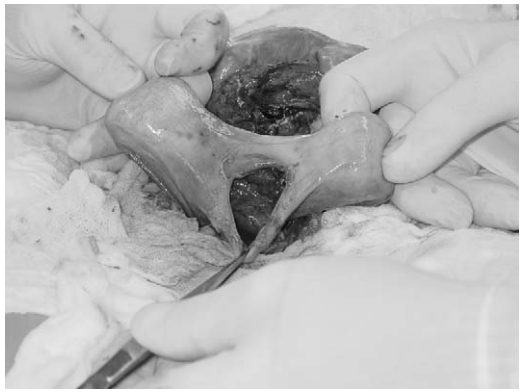

Fig. 1. Uterine rupture in a cat diagnosed 36 hours after the delivery of a healthy kitten. Two fetuses were present within the abdominal cavity. No signs of straining were noted after delivery of the first kitten.

fetuses emerge before their placentas are passed. Lochia, a greenish vaginal discharge, indicates placental separation and is typically seen shortly before the onset of stage 2 labor. After parturition, the discharge gradually becomes reddish brown, decreasing in volume over 4 to 6 weeks as uterine involution takes place.

Each puppy or kitten emerges covered by the amniotic membranes. The chorioallantois typically ruptures during the birthing process or is chewed by the dam as it begins to protrude through the birth canal. The bitch or queen removes the amnion from the neonate by chewing or licking thoroughly, and this also serves to clean the newborn and stimulate respiration. The umbilical cord is severed by biting, and the placenta is typically swallowed. Diarrhea may result if too many placentas are consumed. If the dam fails to care for her newborns, the owner must intervene, removing the amnion and carefully cleaning and drying the neonate with a soft dry towel. Fluid may be removed from the oral and nasal passages with a bulb syringe if needed. The umbilicus should be clamped, transected, and ligated approximately 1 to 2 cm from the newborn's body and then disinfected with iodine.

Dystocia

Dystocia (Greek *dys* [difficult], *tokos* [birth]) is defined as the inability to expel fetuses through the birth canal during parturition and may result from maternal or fetal factors that prevent delivery from taking place (Box 1). Dystocia related to maternal factors may be further classified based on whether it results from myometrial failure (physiologic) or obstruction of the birth canal (morphologic). Uterine inertia is the most common cause of dystocia [4,10–12], seen when the myometrium produces only weak and infrequent contractions that fail to expel a normal fetus through a normal

Box 1. Causes of dystocia

- Maternal
  - Physiologic
    - Primary uterine inertia
      - Hereditary
      - Stress/environmental disturbances
      - Old age
      - Obesity
      - Systemic disease
      - Uterine overdistention (eg, large litter size, fetuses too big)
      - Uterine underdistention (eg, small litter size, inadequate fetal fluids)
      - Estrogen/progesterone balance
      - Calcium/magnesium balance
      - Inadequate oxytocin secretion
      - Prematurity
    - Secondary uterine inertia
- Morphologic
  - Primary (eg, birth canal too small)
  - Secondary (eg, abnormal influence on or within birth canal)
    - Pelvic fractures
    - Uterine torsion
    - Uterine rupture
    - Uterine herniation
    - Uterine prolapse
    - Mass-like lesions of pelvic canal, uterus, vagina, or vulva (eg, hyperplasia, neoplasia, hematoma, abscess)
    - Fibrosis of uterus, cervix, or vagina
    - Vaginal septum
- Fetal
  - Malpresentation
  - Oversize (eg, single fetus pregnancy)
  - Fetal death
  - Fetal malformations

birth canal. Primary uterine inertia is considered complete when gestation has exceeded its expected length with no evidence of progression into active labor. Occasionally, a dog initiates parturition and expels one or more healthy fetuses but then subsequently fails to deliver the remaining fetuses as a result of myometrial fatigue, and this may be referred to as primary partial uterine inertia. Uterine inertia may also be considered secondary if myometrial failure results from prolonged attempts to expel an obstructed fetus and persists after relief of obstruction. Morphologic causes of dystocia

are those in which an anatomic abnormality of the bitch or queen results in obstruction of the birth canal. Primary morphologic abnormalities are commonly seen in narrow-hipped dogs like Bulldogs, Boston Terriers, and Scottish Terriers, where the birth canal is too small to allow passage of a fetus that is considered to be of normal size for the breed [13]. Secondary morphologic causes of dystocia result from an abnormal influence on or within the birth canal (eg, pelvic fractures) that leads to obstruction.

Fetal factors that may result in dystocia include malpresentations, oversize, fetal malformations, and fetal death. Malpresentations are reported to be the second most common cause of dystocia in dogs and cats [4,10–12]. Some of the commonly described malpresentations include transverse presentation, lateral or ventral flexion of the neck, anterior presentation with flexion of one or both forelimbs, posterior presentation with retention of both hind limbs, and simultaneous presentation of two fetuses. It should be noted that posterior presentations are considered to be a normal variation in dogs and cats, occurring in approximately 40% of deliveries [4]. Fetal oversize is another potential cause of dystocia, most commonly seen with single pup pregnancies. Because maternal size largely dictates the size of the offspring, mating between dogs of dissimilar sizes is not a common cause of fetal oversize. Fetal death is an infrequent cause of dystocia, increasing the likelihood of malpresentation because of failure to rotate and extend the head and legs, which commonly occurs immediately before parturition. Fetal malformations are another potential cause of dystocia, with anasarca (generalized subcutaneous edema), hydrocephalus, cerebral and cerebrospinal hernias, abdominal hernias, duplications, and rib cage malformations among the more commonly noted [10,11,14].

A number of breeds have been reported to have a higher prevalence of dystocia. Congenitally narrowed birth canals are seen in many brachycephalic and terrier breeds, such as Bulldogs, Boston Terriers, and Scottish Terriers, and their fetuses may have comparatively large heads, predisposing them to maternal-fetal disproportion [13]. Bulldogs also tend to have slack abdominal musculature that may limit their ability to lift the fetus up toward the birth canal. Many of the small and toy breeds have also been overrepresented in retrospective studies, including Chihuahuas, Pekinese, Yorkshire Terriers, Dachshunds, and Poodles [4]. Golden Retrievers, Labrador Retrievers, and German Shepherds are also heavily featured in retrospective studies, but this is more likely related to the popularity of these breeds than to a true breed predisposition. In feline dystocia, breed and cranial conformation have also been significantly associated with dystocia, with Siamese and Persians heavily overrepresented. In one study looking at the association between cranial conformation and dystocia, the prevalence of dystocia was 10% in dolichocephalic breeds (eg, Siamese, Cornish Rex), 7.3% in brachycephalic breeds (eg, Persian, British Shorthair), and only 2.3% in mesocephalic cats [12]. Uterine inertia and malpresentations were still the most commonly reported causes of dystocia in these breeds.

When an animal is brought in for suspected dystocia (Box 2), it is important to obtain an accurate breeding history. Questions to be asked should include any previous whelping history, the earliest and latest possible breeding dates, the male animal used, the time of temperature drop (if noted), the time of onset of whelping, the frequency and intensity of expulsive efforts, the number and viability of puppies or kittens already delivered, and any interventions used.

A complete physical examination should be performed to rule out the possibility of systemic illness. Abdominal palpation may be helpful to assess the size and tone of the uterus, to estimate the number of remaining fetuses, and to evaluate for the presence of a fetus in the birth canal. If there is no fetus in the pelvic inlet, the animal is not ready to whelp/queen or the uterine horn is unable to expel the fetus. The vulva should be examined for the presence of discharge. Greenish vaginal discharge (lochia) indicates placental separation, and dystocia should be suspected if parturition does not proceed within 2 to 3 hours. Digital examination with a sterile well-lubricated glove should be performed to assess for the degree of cervical dilation (if reachable), fetal position, and the presence of any vaginal or cervical anomalies. If a fetus can be palpated, presentation and viability may be assessed. Gentle feathering of the dorsal vaginal wall should stimulate reflex contractions and can be helpful in assessing their strength.

If a fetus is lodged within the birth canal, digital manipulation should be attempted. The fetus may be grasped around the head and neck, around the pelvis, or around the proximal portions of the hind limbs, depending on fetal presentation. Excessive traction should never be applied to a single

Box 2. Criteria for the suspicion of dystocia

1. A definite cause is visible (ie, fetus lodged in birth canal, pelvic fractures).
2. Gestation is prolonged (>70 days) with no evidence of labor.
3. Temperature has dropped to lower than 100°F and returned to normal with no evidence of labor.
4. Green vaginal discharge (indicates placental separation) or fetal fluids are seen, and 2 hours have elapsed without expulsion of fetuses.
5. Strong and persistent contractions fail to result in the delivery of a puppy within 30 minutes.
6. Weak and infrequent contractions fail to produce a fetus within 4 hours.
7. More than 4 hours have elapsed since the birth of a puppy, with no evidence of ongoing labor.
8. Signs of systemic illness or severe pain are present.

extremity because of the ease with which these may be avulsed. With the dam restrained in a standing position, traction is applied in a posterior-ventral direction. The fetus may be gently rocked back and forth and twisted diagonally to free shoulders and hips ''locked'' in the pelvic canal. If flexion of the head or extremities is preventing delivery, a finger may be used to extend them. One cannot overemphasize the importance of using copious amounts of sterile lubricant (KY Jelly; Johnson & Johnson, New Brunswick, NJ) during obstetric maneuvers, applied digitally or infused around the fetus using a red rubber catheter.

Radiographs should next be obtained in any animal experiencing dystocia. Radiographs are accurate for assessing the number, size, location, and position of fetuses as well as maternal pelvic morphology and the general status of the abdomen. Fetal viability is more difficult to assess from radiographs unless evidence of fetal decomposition is present. The first signs of decomposition to develop include intrafetal gas patterns and awkward fetal postures, such as hyperextension of the extremities, visible by 6 hours postmortem. Collapse of the spinal column because of loss of muscular support and overlapping of the bones of the skull are generally visible by 48 hours postmortem. As more time elapses, accumulation of large amounts of intrauterine gas may occur [15,16]. Ultrasound may be a more useful tool for assessment of fetal viability, fetal malformations, and fetal distress. Normal fetal heart rates have been reported at 180 to 245 beats per minute (bpm) in dogs and up to approximately 265 bpm in cats [17]. Deceleration of fetal heart rates to less than 180 bpm and the presence of fetal bowel movements on ultrasound have been shown to correlate with severe fetal distress and may indicate a need for rapid intervention [18].

Medical management should be considered if there is no evidence of obstruction and fetal and pelvic size appear normal. Calcium gluconate and oxytocin are the agents of choice in medical management of dystocia. Oxytocin is a peptide hormone that increases the frequency and strength of uterine contractions by promoting influx of calcium into myometrial cells. Oxytocin also promotes postpartum uterine involution, aids in control of uterine hemorrhage, and assists in expulsion of retained placentas. The dose of oxytocin has traditionally been reported at 5 to 20 U administered intramuscularly in the dog and 2 to 4 U administered intramuscularly in the cat. With an increase in the use of uterine contraction monitoring in veterinary patients, however, there is a growing body of evidence to suggest that traditional doses may be too high, potentially causing uterine tetany, ineffective contractions, and decreased fetal blood flow. Recent data [5,6] suggest that doses of 0.5 to 2 U are effective in increasing the frequency and quality of contraction. The oxytocin dose may be repeated in 30 minutes if expulsion of a fetus has not resulted. If labor proceeds and a fetus is delivered, oxytocin may be repeated every 30 minutes as needed to assist in expulsion of the remaining fetuses. Oxytocin is contraindicated in obstructive dystocia and uterine inertia secondary to overstretching. Postpartum injections of

oxytocin should be reserved for cases in which a retained placenta is suspected.

Because myometrial contractility is dependent on the influx of extracellular calcium into myometrial cells [19,20], calcium gluconate has been used for many years as an uterotonic agent. Its use should be considered if weak infrequent contractions are noted [5,6], if the initial oxytocin dose was nonproductive [3], or when laboratory work reveals hypocalcemia. Retrospective studies have indicated that many patients failing to respond to oxytocin alone may respond to a combination of calcium and oxytocin [4,11]. The dose for calcium gluconate (10% solution) is 22 mg/kg (50–150 mg/kg if hypocalcemic) diluted in saline and given subcutaneously or added to intravenous fluids and given slowly while monitoring an ECG for arrhythmias. Subcutaneous administration has been reported to result in irritation and potential granuloma formation, although this is an infrequent complication. Dextrose infusion should also be initiated if hypoglycemia is evident on laboratory work.

The prognosis for medical management of dystocia is guarded, with success rates of 20% to 40% in the veterinary literature [4,10–12]. Additionally, stillbirth rates have been shown to rise when dystocia is allowed to continue for longer than 4.5 to 6 hours [4,10] from the time of onset of second-stage labor in the dog. For these reasons, the decision to proceed to cesarian section should not be delayed if the response to medical management is poor or unlikely to result in successful delivery (Box 3).

An anesthetic protocol for cesarian section should be selected with the goal of maximizing the survival of the neonates and dam. Attempts should be made to minimize exposure of the fetus to anesthetics by keeping the time from induction to delivery as short as possible. Ideally, the dam should be clipped and prepared before induction, equipment should be laid out, and the surgeon should be scrubbed and ready. Induction agents should be given to effect. Regional techniques, such as line blocks and epidurals, may help to minimize the need for other drugs. A line block can be performed using lidocaine, 2 mg/kg, infused along the ventral midline [21,22]. Alternately, epidural lidocaine may be administered in dogs at a dose of 2 to 3 mg/kg, not to exceed a total volume of 6 mL [21]. Neonates are poorly able to metabolize anesthetics, so drugs with a short duration of action that are rapidly metabolized by the dam (eg, propofol) or drugs that are reversible (narcotics) should be used. Propofol (4–6 mg/kg administered intravenously) or mask induction is most commonly used for cesarian section at this time and has been associated with reduced neonatal mortality in dogs. Anesthetic agents that have been associated with increased neonatal mortality include thiopental, ketamine, xylazine, medetomidine, and methoxyflurane [23–25]. After induction, the lowest possible concentration of inhalant should be administered until delivery of the puppies. Excessive use of inhalant anesthetics is associated with maternal vasodilation, decreased uterine blood flow, and neonatal depression. Once the puppies are removed, the inhalant

Box 3. Indications for cesarian section

1. Complete primary uterine inertia (consider at 70th day of gestation)
2. Partial primary uterine inertia or secondary uterine inertia; consider cesarian section if large numbers of fetuses remain and response to drugs is unsatisfactory
3. Fetal oversize
4. Gross abnormalities of maternal pelvis (eg, fractures, masses)
5. Fetal malformations
6. Malpresentation that is not amenable to manipulation (eg, transverse presentation)
7. Past history of dystocia or cesarian section; consider planned cesarian section just before full term
8. Fetal putrefaction
9. Maternal evidence of systemic illness
10. Suspicion of uterine torsion, rupture, prolapse, or herniation
11. Evidence of fetal distress with poor response to medical intervention

concentration may be increased if needed and additional analgesics given to the dam. Intravenous fluids should always be administered before and during the procedure to avoid hypotension and decreased fetal blood flow. Pregnant animals may be more susceptible to aspiration pneumonia as a result of delayed gastric emptying. In one prospective multicenter study, 56% of maternal mortalities were related to aspiration pneumonia [23]. Extra care should therefore be taken with airway protection during induction and recovery, particularly if a full stomach is seen on radiographs, and tilting the surgical table in a head down position during surgery should be avoided.

Two techniques have been described for surgical management of dystocia. In the traditional cesarian section or hysterotomy, fetuses are removed one at time from a single incision in the uterine body. Alternately, en bloc ovariohysterectomy may be performed, removing the entire uterus and handing it to a team of assistants for neonatal resuscitation. En bloc ovariohysterectomy may be considered any time disease of the uterus is present (eg, torsion, metritis, fetal putrefaction); surgical speed is required because of the critical condition of the dam; morphologic abnormalities, such as pelvic fractures, prevent future delivery; or an owner does not plan to breed the animal again. Lactation is not adversely affected by ovariohysterectomy, and neonatal survival rates are comparable to those obtained with conventional cesarian section [26]. When performing the en bloc technique, it is critical that the time from the clamping of the uterine artery to the time of newborn extraction is kept to a minimum (30–60 seconds) to minimize the

degree of fetal hypoxia and maximize survival. In recent studies, neonatal survival rates after surgical treatment of dystocia have been reported at 92% at birth, with 80% still alive 7 days after the cesarian section [23,24].

Neonatal resuscitation

A warm (90°F) incubator, hemostats, suture material, suction bulb syringes, emergency drugs, and an adequate supply of soft dry towels should be prepared beforehand. As each puppy is handed off, the umbilical cord should be clamped and ligated 1 to 2 cm from the umbilicus. Fetal fluids and amnion should be removed by rubbing briskly with a soft clean towel. The oral cavity and nares may be suctioned with a bulb syringe. The old practice of "swinging" puppies to clear their airways is best avoided because of the potential for cerebral hemorrhage as a result of concussive injury. If vigorous rubbing is not successful at stimulating respiration, positive-pressure ventilation may be initiated with a snug-fitting mask, keeping the neonate's head and neck extended to ensure adequate inflation of the lungs. Alternately, intubation may be accomplished using a catheter or small uncuffed endotracheal tube. Because isoflurane is minimally metabolized, ventilation is the primary route of elimination. Thus, the depressant effects of isoflurane cannot be reversed until the neonate breathes. Cardiac massage may be instituted if a heart beat cannot be detected once warming and ventilation measures have been instituted. Epinephrine (0.1 mg/kg) may be given intratracheally, intraosseously, or intravenously if cardiac massage is unsuccessful. Naloxone (0.1 mg/kg) should be considered if the dam received opioid analgesics as part of the anesthetic regimen [27]. Although doxapram (Dopram) is routinely administered in many practices as a respiratory stimulant, it is not used for this purpose in the resuscitation of human neonates [28] and there is no evidence to support its use in veterinary patients. Because its effect is diminished when the brain is hypoxic, it is unlikely to be helpful in the apneic newborn [27]. Additionally, there is evidence that doxapram may result in significant decreases in cerebral blood flow that could be detrimental in vulnerable hypoxic newborns [29,30].

Fetal and uterine monitoring

Perinatal monitoring systems are now commercially available (Whelpwise; Veterinary Perinatal Specialties, Wheat Ridge, CO) and are being increasingly used for monitoring and periparturient management of high-risk pregnancies (ie, older dogs, prior history of dystocia, large or small litter size, expensive breedings). Monitoring systems consist of the following equipment: (1) a tocodynamometer attached to a clipped area of the caudal abdomen, which senses changes in intrauterine and intra-amniotic pressure; (2) a recorder worn in a small backpack, which records the uterine contraction

patterns; and (3) a modem for transferring these data to the perinatal service. Owners are also provided handheld Doppler units and are taught to monitor fetal heart rates for evidence of fetal distress.

Uterine monitoring is generally initiated approximately 1 week before the due date, and recordings are taken at home twice daily. The frequency of recording is increased once first-stage labor is entered. Obstetric personnel, available 24 hours a day, interpret the recordings and communicate the results to the client's veterinarian. In this way, much of the guesswork is taken out of management of parturition by providing objective data on the frequency and strength of uterine contractions and allowing definitive diagnosis of uterine inertia and uterine obstructive patterns. Medical treatments using oxytocin and calcium gluconate can be used more accurately, because the effects of these drugs may be directly measured. The decision to proceed to surgery may also be made in a more timely fashion if medical management fails to induce effective uterine contractions, a uterine obstructive pattern develops, or evidence of fetal distress is noted. Correspondingly, studies in bitches after uterine and fetal monitoring have shown significantly lower stillbirth rates (2.5%–3.7%) than previously reported [5,6].

Hemorrhage

Severe uterine hemorrhage (hematometra) and uterine bleeding between heat cycles (metrorrhagia) are uncommon problems in dogs and cats. Differential diagnoses include uterine vessel tear secondary to obstetric trauma, inherited or acquired coagulopathies [31,32], uterine or vaginal masses, subinvolution of placental sites [33], cystic endometrial hyperplasia or pyometra [34], endometritis, uterine serosal inclusion cysts [35], uterine torsion [36], and prepubertal metrorrhagia [37]. If postpartum hemorrhage is mild but persistent and the animal is otherwise clinically normal, oxytocin may be given to hasten resolution by promoting uterine involution. For severe hemorrhage or hemorrhage unrelated to whelping, further investigation is needed. Measurement of baseline packed cell volume (PCV) and total solids (TS), a minimum database (complete blood cell count [CBC], serum biochemistry, and urinalysis), and coagulation testing should be performed. Remember that the hematocrit in the periparturient dog normally decreases to approximately 30%. Evidence of severe anemia in conjunction with clinical signs, such as tachycardia, tachypnea, anorexia, weakness, or altered mentation, may indicate a need for packed red blood cell transfusion, however. Fresh-frozen plasma transfusion should be considered if clotting times are prolonged. Vaginal cytologic examination may help to raise the index of suspicion for endometritis or pyometra, and ultrasound may be helpful to identify mass lesions or other uterine abnormalities. Depending on the cause of the bleeding, or if a definitive cause is not identified, ovariohysterectomy may be indicated.

Uterine prolapse

Uterine prolapse is a rare postpartum complication reported more commonly in cats than in dogs [38,39]. It is generally only seen during or immediately after parturition, because the cervix must be open for prolapse to occur. Reported causes include severe tenesmus during or after parturition, incomplete placental separation, relaxation or atony of the uterus, and excessive relaxation of the pelvic and perineal regions [38]. If the uterus prolapses into the cranial vagina, nonspecific signs of abdominal pain and straining may be noted. In the case of complete uterine prolapse, a large mass of tissue protrudes visibly through the vaginal orifice, with varying degrees of tissue edema, ulceration, and necrosis, depending on the duration and severity of the prolapse. Symptoms of hemorrhagic shock frequently develop after uterine prolapse as a result of ovarian or uterine vessel rupture and may necessitate emergency laparotomy (Fig. 2).

Treatment consists of initially lubricating and protecting the exposed tissues while the animal is treated with intravenous fluids to correct shock. Blood transfusion may be required if severe hemorrhage has occurred. Systemic antibiotics should be administered in any patient in which tissue necrosis is seen. Once the animal is stable, general anesthesia is administered to allow reduction of the prolapse. If uterine tissues are relatively healthy and no further fetuses are present, the tissues should be gently cleaned, lubricated, and then replaced manually. A test tube may be used to invert and reduce the uterus, and hydropulsion with a red rubber catheter and sterile saline may enable proper positioning of the uterine horns. If the prolapse cannot be reduced because of severe tissue edema, a dorsal episiotomy may be performed to facilitate reduction. Oxytocin should be administered after reduction to promote uterine involution. Planned laparotomy should be considered after reduction to ensure proper positioning of the uterine horns and assess the integrity of the uterine vessels. If there is any evidence of

Fig. 2. Uterine prolapse in a cat.

compromised tissue viability or if further breeding is not desired, an ovariohysterectomy should be performed.

In cases in which manual reduction is unsuccessful, surgical reduction may be necessary, allowing the surgeon to apply traction from the abdomen while an assistant applies external pressure. Once reduced, the uterus may then be pexied to the ventrolateral body wall to prevent recurrence. If reduction is not possible because of severe tissue swelling or necrosis, amputation of the traumatized external tissue may be needed before the remainder can be reduced. The urethra should be catheterized during this process to prevent accidental trauma. After resection of the necrotic segment, the remaining tissue is reduced and a laparotomy is performed to complete the ovariohysterectomy.

Uterine torsion

Uterine torsion is a complication of pregnancy that has been reported infrequently in dogs and cats. Although it typically occurs in multiparous animals late in pregnancy or at the time of parturition, uterine torsion has also been reported in nonpregnant nulliparous animals and as a complication of pyometra [36,40]. The cause of uterine torsion is unknown, but contributing factors may include excessive fetal movement, lack of uterine tone, lack of fetal fluids, and previous stretching of the broad ligament in multiparous animals. Uterine torsions most commonly involve a single uterine horn twisted at its base, but torsions of both horns or the uterine body have also been described [36]. Clinical signs are variable and include abdominal pain, shock, hypothermia, hemorrhagic vaginal discharge, dystocia (with continuous straining), vomiting, and restlessness. Torsions of 180° may persist for weeks without clinical signs until labor ensues [41].

Radiography or ultrasonography may show evidence of a fluid-filled uterus, fetal death, or peritoneal effusion, but results may be nonspecific. Exploratory surgery is usually required for definitive diagnosis and treatment. As with other forms of torsion, uterine torsion should not be corrected before ovariohysterectomy to prevent release of endotoxins and inflammatory mediators contained within the compromised tissue [42]. The prognosis is generally good if shock is corrected and surgery is performed in a timely fashion.

Mastitis

Mastitis is a postpartum complication seen in dogs and cats that results from bacterial infection of the mammary glands. Bacteria most commonly enter through the nipple as a result of nursing, trauma, or poor hygiene but may also be spread hematogenously. In mild cases, discomfort, swelling, and inflammation may be seen, whereas in severe cases, signs of systemic illness,

such as fever, anorexia, and lethargy, frequently develop. Dogs often refuse to allow their young to nurse and may be reluctant to lie down. Severe mastitis often progresses to abscessation and necrosis.

A diagnosis of mastitis is generally based on history and clinical signs (fever and swollen painful glands in the postpartum animal), but a baseline CBC and chemistry testing as well as milk cytologic testing and culture are useful for assessing the severity of illness and appropriateness of antibiotic selection. Milk expressed from the gland may be purulent, stringy, hemorrhagic, or gray, and cytologic examination typically shows large numbers of white blood cells and intracellular bacteria. The most common bacteria isolated on culture include *Escherichia coli*, staphylococci, and streptococci.

Treatment is initiated immediately with broad-spectrum antibiotics. Amoxicillin-clavulanic acid (Clavamox, Augmentin) or cephalexin (Keflex) is a good first choice; both are safe for nursing neonates. Trimethoprim-sulfamethoxazole ([TMZ-SMP], Tribrissen), chloramphenicol, and clindamycin (Antirobe) are other useful antibiotics reported to achieve high concentrations in milk [43]. Other measures that may be useful in the management of mastitis include warm compresses, hydrotherapy, and frequent milk stripping. If a fluctuant abscess pocket is identified on palpation, early lancing and flushing may limit the degree of skin necrosis that follows. Large ruptured mammary abscesses may be successfully managed as open wounds with warm compresses, hydrotherapy, and systemic antibiotics, but in these cases, mastectomy may provide a more rapid and cosmetic resolution of the problem.

Endometritis

Endometritis is a bacterial infection of the uterus that is generally seen within the first 3 days (up to 1 week) after whelping, although it may develop during pregnancy as well. Potential causes include retained fetuses or placentas, abortions, uterine trauma secondary to dystocia or obstetric manipulation, and ascending infection from the vaginal canal. Typical signs include fever, lethargy, anorexia, vomiting, diarrhea, poor lactation, neglect of offspring, and a foul-smelling vaginal discharge. Just as in the nonpregnant dog, any purulent vaginal discharge noted during or after pregnancy is abnormal and should prompt investigation.

Laboratory work abnormalities consistent with sepsis may be seen, including leukocytosis with a left shift or leukopenia, thrombocytopenia, elevated liver values, and hypoalbuminemia. Coagulation testing should be performed to rule out disseminated intravascular coagulation. Radiography or ultrasound is indicated to evaluate for fetal death, retained placentas, or evidence of uterine enlargement. Cytologic examination of vaginal discharge typically shows degenerate neutrophils and macrophages with intracellular bacteria. The most common organisms associated with uterine infections

include staphylococci, streptococci, *E coli*, *Salmonella*, *Campylobacter*, and *Chlamydia* [44].

An animal suspected of having septic metritis should be treated aggressively with intravenous fluids. Broad-spectrum antibiotic combinations, such as ampicillin-enrofloxacin, ampicillin-aminoglycoside, or cefazolin-aminoglycoside-metronidazole, should be administered. After stabilization, ovariohysterectomy is the treatment of choice for metritis. If the animal is not showing signs of sepsis and the owner wishes to use it for breeding purposes in the future, evacuation of the uterine contents using $PGF_{2\alpha}$ (Lutalyse) may also be attempted in conjunction with broad-spectrum antibiotics (see section on pyometra for protocol). Potential complications of $PGF_{2\alpha}$ include vomiting, abdominal discomfort, uterine rupture, and septic peritonitis. Because $PGF_{2\alpha}$ treatment may require several days to achieve a good effect, animals that are severely ill should always be treated with ovariohysterectomy. Ovariohysterectomy is also the best choice when the animal is not intended for future breeding or if the health of the dam is a higher priority than possible future breedings.

Eclampsia

Eclampsia or puerperal tetany is a life-threatening condition that results from the development of hypocalcemia in the periparturient period. It is one of the more common complaints noted after parturition, accounting for 23% of periparturient emergencies in one study [45]. Eclampsia is believed to result from the loss of calcium through lactation and fetal skeletal mineralization in excess of that entering the extracellular fluid through gastrointestinal absorption and bone resorption. Other factors, such as inadequate diet or parathyroid atrophy resulting from oversupplementation of calcium, may also contribute, although the diet in affected animals was not significantly different from that in nonaffected animals in retrospective studies [45,46]. An increasing ratio of litter size to maternal body weight has also been identified as a significant factor in the development of periparturient hypocalcemia [45].

Eclampsia is most commonly seen in small dogs, first-time whelpings, and dogs with large litter sizes. It typically develops 2 to 4 weeks after parturition [45,47] but is occasionally seen in late gestation [46]. Clinical signs in dogs most commonly include stiff gait, trembling, twitching, seizures, tachycardia, panting, and hyperthermia, but approximately 20% of dogs may present with atypical signs, such as whining, vomiting, diarrhea, and behavior changes [45]. If untreated, death may result from respiratory impairment or from hyperthermia and cerebral edema. Cats may demonstrate clinical signs similar to those of dogs but, unlike dogs, are more prone to hypothermia and may present with hyperexcitability, hypersensitivity, or flaccid paralysis in place of clonic-tonic muscle spasms [46].

A diagnosis of eclampsia is made on the basis of history and physical examination findings in conjunction with low total or ionized calcium levels. Ionized calcium represents the physiologically active portion of calcium within the body and is involved in muscular contraction as well as neurologic and cardiovascular function. Ionized calcium levels are thus believed to be a more sensitive indicator of extracellular calcium levels than total calcium and typically fall to less than 0.8 mmol/L in dogs with eclampsia (reference range: 1.2–1.4 mmol/L). In one study [48], however, total calcium levels were found to be decreased in all dogs with eclampsia, suggesting that total calcium levels may provide sufficient information in this disease if an ionized calcium measurement is not available.

Animals presented with eclampsia should have an intravenous catheter placed and intravenous fluids administered to address fever, dehydration, and tachycardia. Calcium gluconate (10%) should immediately be administered intravenously slowly to effect. Most animals have tremors controlled at doses ranging from 0.5 to 1.5 mL/kg. ECG should be monitored during calcium administration, and the infusion should be stopped if bradycardia or arrhythmias develop. Ionized calcium levels should be rechecked after administration to make sure that ionized calcium levels remain within the normal range. Temperature should be carefully monitored in animals presenting with tremors, and active cooling measures (eg, cool fluids, wetting the hair coat, and fan blowing over the animal) should be instituted for patients with severe hyperthermia. Body temperature generally falls quickly once tremors are controlled, so active cooling measures should be discontinued once the animal's temperature falls below 103°F. Oral calcium carbonate (Tums) supplementation should be continued at a dose of 100 mg/kg/d throughout lactation. Up to 20% of dogs [47] may have recurrence of eclampsia despite supplementation if puppies are allowed to nurse, so bottle feeding and early weaning of the puppies are recommended.

Supplementation of calcium before whelping is not recommended because this may downregulate parathyroid hormone secretion, decreasing intestinal calcium absorption and increasing the risk of eclampsia during lactation. Instead, calcium administration (100 mg/kg/d divided) should be instituted after whelping in dogs at risk and dogs with a previous history of eclampsia.

Pyometra

Pyometra, the accumulation of purulent exudate within the uterine lumen, is a hormonally mediated disease seen during diestrus in dogs and cats. It is typically but not always [49] preceded by cystic endometrial hyperplasia (CEH), an abnormal uterine response to progesterone. During diestrus, a period of approximately 70 days when the uterus is under the influence of progesterone produced by the corpus luteum, dogs with CEH develop excessive proliferation of mucus-producing glands, leading to endometrial

thickening. Increased glandular activity in conjunction with decreased myometrial activity may lead to fluid accumulation in the uterus, referred to as mucometra or hydrometra at this stage, depending on the viscosity of the fluid. With continued progesterone stimulation, the uterine response may become inflammatory, with infiltration of lymphocytes and plasma cells into the endometrium. CEH typically resolves once progesterone levels decrease at the end of diestrus but may worsen with subsequent cycles.

Estrogen by itself does not cause CEH or pyometra but may contribute to its development. In one experimental study, CEH could not be produced by exogenous administration of estrogen to ovariectomized dogs but did develop when estrogen was given in conjunction with progesterone [50]. Estrogen is therefore believed to enhance the stimulatory effects of progesterone on the uterus, but the mechanism by which this occurs is poorly understood [51]. Thus, exogenous estrogen (eg, mismate shots, diethylstilbestrol) given during estrus or diestrus may greatly increase the risk of developing pyometra and has been implicated as one of the most common factors in the development of pyometra in young animals [52].

The changes associated with CEH set up a favorable environment for secondary bacterial infection. The most common source of these bacteria is from the normal vaginal vault flora, which may enter through the open cervix during proestrus and estrus. Vaginal populations of bacteria have not been shown to differ between dogs that develop pyometra and those that do not [53], suggesting opportunistic invasion of the abnormal progesterone-primed uterus. There is some evidence to suggest that high progesterone levels may decrease phagocytic activity within the uterus and that estrogen may promote the inhibitory actions of progesterone on uterine bactericidal activity [54]. *E coli* is the bacterium most commonly isolated from dogs and cats with pyometra, possibly as a result of its ability to adhere to receptors in the progesterone-primed uterus [55]. Other bacteria commonly implicated in the development of pyometra include *Staphylococcus*, *Streptococcus*, *Klebsiella*, *Pseudomonas*, and *Proteus* [56–60]. During pyometra, release of bacterial endotoxin occurs and may indirectly account for many of the adverse effects associated with pyometra, including cardiovascular collapse, altered renal function, hepatocellular injury, and disseminated intravascular coagulation. Blood endotoxin levels have been shown to be significantly different between healthy dogs and dogs with pyometra, and higher endotoxin levels were associated with a worse outcome in one study [58]. Endotoxin levels decreased significantly in all dogs after surgery.

Pyometra is considered to be a disease of middle-aged to older dogs that have been through numerous heat cycles and have therefore undergone repetitive progesterone stimulation of the uterus. Progesterone levels in dogs with pyometra were not shown to be different from those of unaffected dogs [61], possibly explaining why repetitive cycles (ie, older dogs) are necessary to cause disease. An increasing frequency of pyometra has been reported in younger dogs, however. In a study of 57 bitches with pyometra that were

treated with $PGF_{2\alpha}$, the mean age was 2.5 years [52]. Pyometra is also seen in cats but less frequently than in dogs, because cats are induced ovulators that require intercourse before luteal activity and progesterone secretion occur. The use of megestrol acetate (Ovaban) and the presence of retained corpora lutea [52,56,57] are factors that have been associated with an increased likelihood of developing pyometra in cats.

Historical findings in animals presenting with pyometra classically include vulvar discharge, anorexia, depression, polyuria, polydipsia, vomiting, and diarrhea. Signs typically develop 1 to 2 months after estrus. If signs are recognized early, the animal may appear otherwise healthy. The longer it takes for signs to be recognized by the owner, the more likely it is that severe signs of dehydration, sepsis, or shock as well as death will occur. The fact that most closed-cervix pyometras present with more severe symptoms than open-cervix pyometras likely reflects the lack of an obvious sign that owners can recognize, leading to a prolonged clinical course before veterinary attention is sought.

On physical examination, purulent vulvar discharge is often the most obvious sign. The uterus may be palpably enlarged, depending on uterine turgor, the size of the animal, and the degree of abdominal relaxation. Caution should be taken during palpation to avoid rupture of the friable uterus. Rectal temperature is often normal but may be elevated as a result of uterine inflammation and septicemia. With decompensatory septic shock, hypotension, hypothermia, tachycardia, pale mucous membranes, and prolonged capillary refill time may be noted.

Anemia of chronic disease is a common finding in animals with pyometra, occurring in approximately 70% of cases [62]. The anemia is generally non-regenerative, normocytic, and normochromic but may progress to a microcytic and hypochromic anemia, especially when there is concurrent blood loss. Leukocytosis is another common finding, often exceeding 30,000/μL, accompanied by a left shift. Normal or only mildly elevated white blood cell counts may be seen in dogs with open pyometra, however [52]. Serum chemistry frequently shows hyperproteinemia secondary to dehydration, although hypoalbuminemia may also result from sepsis. Hyperglycemia may be seen initially because of catecholamine release and peripheral insulin resistance. As sepsis progresses, decreased gluconeogenesis, depletion of glycogen stores, and increased peripheral glucose use may result in hypoglycemia. Elevations in alanine aminotransferase and alkaline phosphatase may occur secondary to hepatocellular damage from hypovolemia or sepsis. Azotemia is another frequent finding reported in 12% to 37% of animals with pyometra [56,59] and may be prerenal or renal in origin. One study identified a 75% incidence of renal dysfunction in dogs with pyometra. Tubulointerstitial nephritis was the lesion seen most commonly on renal biopsy, but lesion severity did not correlate with degree of functional loss [59]. Endotoxemia is believed to result in reversible renal tubular damage, reducing the sensitivity of the renal tubules to the effects of antidiuretic

hormone (ADH) and leading to decreased concentrating ability. Urine specific gravity may be concentrated early in the course of disease as a result of dehydration but frequently becomes isosthenuric (1.007–1.017) or hyposthenuric (1.001–1.006) because of the effects of endotoxin on the renal tubules. This can make it challenging to distinguish renal from prerenal causes of azotemia, but seeing decreases in BUN and creatinine immediately after fluid therapy would support a prerenal cause. Azotemia unresponsive to fluid therapy suggests acute tubular necrosis and may carry a more guarded prognosis, although renal values may improve after ovariohysterectomy. Concurrent urinary tract infections have been reported in 22% to 72% [55,56,59] of animals with pyometra and should be suspected if pyuria, hematuria, or proteinuria is seen on urinalysis. Cystocentesis should not be performed before surgery because of the risk of puncturing the infected uterus, but a sample for cystocentesis may be collected at the time of surgery.

Vaginal cytologic examination typically shows large numbers of degenerative neutrophils with intracellular bacteria. Vaginoscopy may be helpful in determining the origin of the discharge but is not routinely performed in the emergency setting. Anterior vaginal cultures using a shielded swab may be valuable for determining antibiotic sensitivity when managing pyometra medically. Vaginal and uterine cultures have been reported to be negative in 10% to 30% of cases [56,60,63].

Radiographs frequently show a large tubular structure in the caudoventral abdomen, and loss of abdominal detail may be present if uterine rupture has occurred. An inability to identify the uterus on radiographs does not rule out pyometra, because drainage associated with open pyometra may prevent significant distention from being appreciable. Pregnancy is one of the most important differential diagnoses for pyometra and cannot be differentiated from pyometra radiographically until approximately day 42, when fetal skeletal mineralization is sufficient to be detected. Ultrasound may therefore be a more accurate way to assess the uterus, allowing visualization of the uterine size, wall thickness, and presence of fluid and fetal structures.

Once pyometra has been diagnosed, ovariohysterectomy is strongly recommended unless the owner desires the animal solely for breeding purposes. Before inducing anesthesia, aggressive fluid therapy should be directed toward correction of shock, electrolyte and acid-base abnormalities, and hypoglycemia. Crystalloids, such as lactated Ringer's solution, are initially a good choice, with colloidal solutions, such as hetastarch, added if hypoalbuminemia and decreased oncotic pressure are a concern. Hypertonic saline has also been shown to be a beneficial adjunct therapy in patients with septic shock undergoing ovariohysterectomy for pyometra [64]. Fresh-frozen plasma (10 mL/kg) may be indicated if coagulation testing reveals prolonged clotting times. Broad-spectrum antibiotics should be administered before surgery and continued for 10 days after surgery. Once the animal is relatively stable, surgery should be performed. Severe clinical signs associated with

pyometra are related to septicemia and endotoxemia; consequently, they do not resolve until the source of infection is removed.

At the time of surgery, the uterus may be large and friable, and caution should be taken to avoid uterine laceration on entry or accidental rupture or spillage during manipulation of the uterus. The uterus should be exteriorized and packed off with laparotomy sponges to avoid abdominal contamination and then removed using a triple-clamp technique. The uterine stump should not be oversewn because this may increase the risk of abscessation by "walling off" a portion of the infected stump. Rather, the stump should be gently cleaned and lavaged before closure. In the event of accidental abdominal contamination, copious lavage with sterile saline should be performed. The prognosis for surgically managed pyometra is generally good, with a reported survival of approximately 92% in dogs and cats [56,58]. The development of severe generalized peritonitis resulting from uterine rupture carries a more guarded prognosis, however, frequently necessitating closed-suction drain placement or management using open abdominal drainage techniques to maximize the chances for a positive outcome.

Medical management of pyometra is generally discouraged because of the possibility of severe complications, adverse effects, and a high recurrence rate. If an animal is valued solely for breeding purposes, however, and if signs of systemic illness are mild, medical therapy may be attempted. $PGF_{2\alpha}$ (Lutalyse) is currently the medical therapy of choice, resulting in resolution of pyometra in 75% to 100% of dogs and cats with open-cervix pyometra and successful breeding in approximately 90% [52,60,63,65,66]. Actions of $PGF_{2\alpha}$ include contraction of the myometrium and relaxation of the cervix, leading to evacuation of the uterine contents. The luteolytic effects of $PGF_{2\alpha}$ may also result in decreased progesterone levels, removing some of the stimulus for CEH. Considerations for deciding on medical versus surgical management should include age and reproductive status of the animal, severity of illness, and the type of pyometra (open or closed cervix). Medical management should be strongly discouraged in older animals or animals not intended for breeding. Additionally, because $PGF_{2\alpha}$ generally does not result in clinical improvement for at least 48 hours [60], surgical management is still the treatment of choice for severely ill animals. $PGF_{2\alpha}$ should also be used with caution in animals with closed-cervix pyometra because of the increased risk of uterine rupture and the possibility of retrograde expulsion of exudate through the oviducts into the abdomen. When used in these animals, success rates of 25% to 41% have been reported [52,60,65].

$PGF_{2\alpha}$ is typically administered subcutaneously at a dose of 0.1 to 0.25 mg/kg once daily for 5 days. Only naturally occurring $PGF_{2\alpha}$ (Lutalyse) should be used, because the synthetic analogues are more potent and could be fatal at this dose range. The lower dose is often used initially to assess an individual animal's response before increasing the dose if needed. Because positive blood cultures have been reported after treatment [60], antibiotic therapy should be started empirically using amoxicillin-clavulanate

(Clavamox, Augmentin), enrofloxacin (Baytril), or TMZ-SMP (Tribrissen) and then continued for 14 days based on the results of anterior vaginal cultures. $PGF_{2\alpha}$ is associated with a number of adverse effects that are commonly seen after injection. Initial signs may include restlessness, panting, and pacing, followed by hypersalivation, tachycardia, abdominal pain, fever, or vomiting. Cats may additionally show signs of mydriasis, vocalizing, excessive grooming, tenesmus, or lordosis [63]. Symptoms typically last for 30 to 60 minutes after injection and decrease in severity with subsequent injections. Variable evidence of uterine evacuation may be seen after injections. Because of the risk of complications and adverse effects, animals should be hospitalized during medical management of pyometra for observation and supportive care. Resolution of clinical signs, clearing and ultimate cessation of vaginal discharge, decrease in uterine size, and resolution of neutrophilia are indications of a good response to medical management. In contrast, persistent symptoms of tachycardia, tachypnea, fever, hypothermia, depressed mentation, abdominal pain, and vomiting should raise concerns about the possibility of uterine rupture or peritonitis and should prompt immediate attention. Recently, a low-dose protocol for $PGF_{2\alpha}$ (0.02 mg/kg administered subcutaneously three times daily for 8 days) has been used successfully with fewer reported side effects [66].

Animals treated with $PGF_{2\alpha}$ should be rechecked 2 weeks after completion of treatment. The presence of purulent discharge, fever, neutrophilia, or uterine enlargement is an indication for a second 5-day course of treatment. Retrospective reports indicate that approximately 64% of dogs [52] and 95% of cats [63] with open-cervix pyometra have a good outcome after a single course of therapy, with 93% of dogs having a good response after a second 5-day course. Recurrence has been reported in up to 77% of dogs within 27 months of initial therapy [67]. Therefore, breeding is recommended on the first cycle after treatment so as to maximize the reproductive potential of the bitch and to minimize the possibility of recurrence. Once the animal is no longer used for breeding, an ovariohysterectomy should be performed.

References

[1] Concannon P, Whaley S, Lein D, et al. Canine gestation length: variation related to time of mating and fertile life of sperm. Am J Vet Res 1983;44:1819–21.
[2] Johnson CA. Disorders of pregnancy. Vet Clin N Am Small Anim Pract 1986;16:477–82.
[3] Feldman EC, Nelson RW. Breeding, pregnancy, and parturition. In: Canine and feline endocrinology and reproduction. Philadelphia: WB Saunders; 1987. p. 547–71.
[4] Gaudet DA. Retrospective study of 128 cases of canine dystocia. J Am Anim Hosp Assoc 1985;21:813–8.
[5] Copley K. Comparison of traditional methods for evaluating parturition in the bitch versus using external fetal and uterine monitoring. In: Proceedings of the Society of Theriogenology Annual Conference, Colorado Springs, CO, 2002. Society of Theriogenology. p. 375–82.
[6] Davidson AP. Uterine and fetal monitoring in the bitch. Vet Clin N Am Small Anim Pract 2001;31:305–13.

[7] Concannon PW, McCann JP, Temple M. Biology and endocrinology of ovulation, pregnancy, and parturition in the dog. J Reprod Fertil Suppl 1989;39:3–25.
[8] Linde-Forsberg C, Eneroth A. Parturition. In: Simpson GM, editor. Manual of small animal reproduction and neonatology. Cheltenham: British Small Animal Veterinary Association; 1998. p. 127–42.
[9] Root MV, Johnston SD, Olson PN. Estrous length, pregnancy rate, gestation and parturition lengths, litter size, and juvenile mortality in the domestic cat. J Am Anim Hosp Assoc 1995;31:429–33.
[10] Darvelid AW, Linde-Forsberg C. Dystocia in the bitch: a retrospective study of 182 cases. J Small Anim Pract 1994;35:402–7.
[11] Eckstrand C, Linde-Forsberg C. Dystocia in the cat: a retrospective study of 155 cases. J Small Anim Pract 1994;35:459–64.
[12] Gunn-Moore DA, Thrusfield MV. Feline dystocia: prevalence, and association with cranial conformation and breed. Vet Rec 1995;136:350–3.
[13] Cruz R, Alvarado MS, Sandoval JE, et al. Prenatal sonographic diagnosis of fetal death and hydranencephaly in two Chihuahua fetuses. Vet Radiol Ultrasound 2003;44:589–92.
[14] Eneroth A, Linde-Forsberg C, Uhlhorn M, et al. Radiographic pelvimetry for assessment of dystocia in bitches: a clinical study of two terrier breeds. J Small Anim Pract 1999;40:257–64.
[15] Farrow CS, Morgan JP, Story EC. Late term fetal death in the dog: early radiographic diagnosis. J Am Vet Radiol 1976;17:11–7.
[16] Farrow CS. Maternal-fetal evaluation in suspected canine dystocia: a radiographic perspective. Can Vet J 1978;19:24–6.
[17] Verstegen JP, Silva LDM, Onclin K, et al. Echocardiographic study of heart rate in dog and cat fetuses in utero. J Reprod Fertil Suppl 1993;47:175–80.
[18] Zone MA, Wanke MM. Diagnosis of canine fetal health by ultrasonography. J Reprod Fertil Suppl 2001;57:215–9.
[19] Wray S, Kupittayanant S, Shmygol A, et al. The physiological basis of uterine contractility: a short review. Exp Physiol 2001;86:239–46.
[20] Wray S, Jones K, Kupittayanant S, et al. Calcium signaling and uterine contractility. J Soc Gynecol Investig 2003;10:252–64.
[21] Pascoe PJ, Moon PF. Periparturient and neonatal anesthesia. Vet Clin N Am Small Anim Pract 2001;31:315–41.
[22] Gilroy BA, DeYoung DJ. Caesarian section: anesthetic management and surgical technique. Vet Clin N Am Small Anim Pract 1986;16:483–93.
[23] Moon PF, Erb HN, Ludders JW, et al. Perioperative management and mortality rates of dogs undergoing cesarian section in the United States and Canada. J Am Vet Med Assoc 1998;213:365–9.
[24] Moon-Massat PF, Erb HN. Perioperative factors associated with puppy vigor after delivery by cesarian section. J Am Anim Hosp Assoc 2002;38:90–6.
[25] Funkquist PME, Nyman GC, Lofgren AMJ, et al. Use of propofol-isoflurane as an anesthetic regimen for cesarian section in dogs. J Am Vet Med Assoc 1997;211:313–7.
[26] Robbins MA, Mullen HS. En bloc ovariohysterectomy as a treatment for dystocia in dogs and cats. Vet Surg 1994;23:48–52.
[27] Moon PF, Massat BJ, Pascoe PJ. Neonatal critical care. Vet Clin N Am Small Anim Pract 2001;31:343–67.
[28] Kattwinkel J, Niermeyer S, Nadkarni V, et al. Resuscitation of the newly born infant: an advisory statement from the Pediatric Working Group of the International Liaison Committee on Resuscitation. Circulation 1999;99:1927–38.
[29] Roll C, Horsch S. Effects of doxapram on cerebral blood flow velocity in preterm infants. Neuropediatrics 2004;35:126–9.
[30] Miletich DJ, Ivankovich AD, Albrecht RF, et al. The effects of doxapram on cerebral blood flow and peripheral hemodynamics in the anesthetized and unanesthetized goat. Anesth Analg 1976;55:279–85.

[31] Wheeler SL, Weingand KW, Thrall MA, et al. Persistent uterine and vaginal hemorrhage in a beagle with factor VII deficiency. J Am Vet Med Assoc 1984;185:447–8.
[32] Padgett SL, Stokes JE, Tucker RL, et al. Hematometra secondary to anticoagulant rodenticide toxicity. J Am Anim Hosp Assoc 1998;34:437–9.
[33] Dickie MB, Arbeiter K. Diagnosis and therapy of the subinvolution of placental sites in the bitch. J Reprod Fertil Suppl 1993;47:471–5.
[34] Troxel MT, Cornetta AM, Pastor KF, et al. Severe hematometra in a dog with cystic endometrial hyperplasia/pyometra complex. J Am Anim Hosp Assoc 2002;38:85–9.
[35] Arnold S, Hubler M, Hauser B, et al. Uterine serosal inclusion cysts in a bitch. J Small Anim Pract 1996;37:235–7.
[36] Shull RM, Johnston SD, Johnston GR, et al. Bilateral torsion of uterine horns in a non-gravid bitch. J Am Vet Med Assoc 1978;172:601–3.
[37] Joshi BP, Humor A. Prepubertal metrorrhagia in bitches: a case study. Indian Vet J 1991;68: 879–80.
[38] Wallace LJ, Henry JD, Clifford JH. Manual reduction of uterine prolapse in a domestic cat. Vet Med Small Anim Clin 1970;65:595–6.
[39] Maxson FB, Krausnick KE. Dystocia with uterine prolapse in a Siamese cat. Vet Med Small Anim Clin 1969;64:1065–6.
[40] Homer BL, Altman NH, Tenzer NB. Left horn uterine torsion in a non-gravid nulliparous bitch. J Am Vet Med Assoc 1980;176:633–4.
[41] Biller DS, Haibel GK. Torsion of the uterus in a cat. J Am Vet Med Assoc 1987;191: 1128–9.
[42] Ridyard AE, Welsh EA, Gunn-Moore DA. Successful treatment of uterine torsion in a cat with severe metabolic and haemostatic complications. J Feline Med Surg 2000;2:115–9.
[43] Feldman EC, Nelson RW. Periparturient diseases. In: Canine and feline endocrinology and reproduction. Philadelphia: WB Saunders; 1987. p. 572–91.
[44] Boothe DM. Treatment of bacterial infections. In: Small animal clinical pharmacology and therapeutics. Philadelphia: WB Saunders; 2001. p. 175–221.
[45] Drobatz KJ, Casey KK. Eclampsia in dogs: 31 cases (1995–1998). J Am Vet Med Assoc 2000; 217:216–9.
[46] Fascetti AJ, Hickman MA. Preparturient hypocalcemia in four cats. J Am Vet Med Assoc 1999;215:1127–9.
[47] Austad R, Bjerkas E. Eclampsia in the bitch. J Small Anim Pract 1976;17:793–8.
[48] Aroch I, Srebro H, Shpigel NY. Serum electrolyte concentrations in bitches with eclampsia. Vet Rec 1999;145:318–20.
[49] De Bosschere H, Ducatelle R, Vermeirsch H, et al. Cystic endometrial hyperplasia-pyometra complex in the bitch: should the two entities be disconnected? Theriogenology 2001;55: 1509–19.
[50] Dow C. Experimental reproduction of the cystic hyperplasia-pyometra complex in the bitch. J Pathol Bacteriol 1959;78:267–78.
[51] De Cock H, Ducatalle R, Tilmant K, et al. Possible role of insulin-like growth factor-I in the pathogenesis of cystic endometrial hyperplasia pyometra complex in the bitch. Theriogenology 2002;57:2271–87.
[52] Nelson RW, Feldman EC. Pyometra. Vet Clin N Am Small Anim Pract 1986;16:561–75.
[53] Olsen P, Mather E. Canine vaginal and uterine bacterial flora. J Am Vet Med Assoc 1978; 172:708–11.
[54] Matsuda H, Okuda K, Fukui K, et al. Inhibitory effect of estradiol-17β and progesterone on bactericidal activity in uteri of rabbits infected with *Escherichia coli*. Infect Immun 1985;48: 652–7.
[55] Sandholm M, Vesenius H, Kivisto AK. Pathogenesis of canine pyometra. J Am Vet Med Assoc 1975;167:1006–10.
[56] Kenney KJ, Matthiesen DT, Brown NO, et al. Pyometra in cats: 183 cases (1979–1984). J Am Vet Med Assoc 1987;191:1130–2.

[57] Potter K, Hancock DH, Gallina AM. Clinical and pathologic features of endometrial hyperplasia, pyometra, and endometritis in cats: 79 cases(1980–1985). J Am Vet Med Assoc 1991;198:1427–31.
[58] Okano S, Tagawa M, Takase K. Relationship of the blood endotoxin concentration and prognosis in dogs with pyometra. J Vet Med Sci 1998;60:1265–7.
[59] Stone EA, Littman MP, Robertson JL, et al. Renal dysfunction in dogs with pyometra. J Am Vet Med Assoc 1988;193:457–64.
[60] Nelson RW, Feldman EC, Stabenfeldt GH. Treatment of canine pyometra and endometritis with prostaglandin $F_{2\alpha}$. J Am Vet Med Assoc 1982;181:899–903.
[61] Chaffaux S, Thibier M. Peripheral plasma concentrations of progesterone in dogs with pyometra. Ann Rec Vet 1978;9:587–92.
[62] de Schepper J, Van Der Stock J, Capiau E. Anaemia and leucocytosis in one hundred and twelve dogs with pyometra. J Small Anim Pract 1987;28:137–45.
[63] Davidson AP, Feldman EC, Nelson RW. Treatment of pyometra in cats using prostaglandin $F_{2\alpha}$:21 cases (1982–1990). J Am Vet Med Assoc 1992;200:825–8.
[64] Fantoni DT, Auler JOC, Futema F, et al. Intravenous administration of hypertonic sodium chloride solution with dextran or isotonic sodium chloride solution for treatment of septic shock secondary to pyometra in dogs. J Am Vet Med Assoc 1999;215:1283–7.
[65] Memon MA, Mickelson WD. Diagnosis and treatment of closed cervix pyometra in a bitch. J Am Vet Med Assoc 1993;203:509–12.
[66] Hubler M, Arnold S, Casal M, et al. Use of a low dose prostaglandin F_2 alpha in bitches. Schweiz Arch Tierheilkd 1991;133:323–9.
[67] Meyers-Wallen VN, Goldschmidt MH, Flickinger GL. Prostaglandin $F_{2\alpha}$ treatment of canine pyometra. J Am Vet Med Assoc 1986;189:1557–61.