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Surgery

A retrospective study of anesthesia for subcutaneous ureteral bypass placement in cats: 27 cases

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ABSTRACT. The goals of this retrospective clinical case series study were to describe the management of anesthesia, and to report perioperative complications in cats undergoing subcutaneous ureteral bypass (SUB) placement due to ureteral obstruction. Medical records of client-owned cats with ureteral obstruction and anesthetized for SUB placement between 2012 and 2015 in a veterinary teaching hospital were reviewed. Twenty-seven cases were identified. Duration of anesthesia and surgery (mean ± standard deviation) were 215 ± 42 min and 148 ± 36 min, respectively. Hypothermia was the most common intraoperative complication. Hypotension, hypocapnia, hypertension and bradycardia were also frequently observed. Out of 22 cats who experienced intraoperative hypotension, 17 received inotropes and vasopressors. There was a significant decrease in creatinine (P=0.008) and total solids (P=0.007) after SUB placement when compared with baseline values. Postoperative complications included pain, anorexia, nausea, hypertension, and urinary tract-related problems. No death occurred in the postoperative period. Successful management of anesthesia for SUB placement involves rigorous anesthetic monitoring and immediate treatment of complications. Perioperative complications appear to be common. This study could not identify risk factors associated with this procedure.

KEY WORDS: anesthesia, feline, subcutaneous ureteral bypass, ureteral obstruction

Feline upper urinary tract obstructions are caused by calculus, soft tissue plugs, neoplasia, fibrosis, inflammation and/or stricture of the ureter [5, 16]. These obstructions can result in decreased glomerular filtration rate and renal blood flow [12, 13], leading to severe kidney damage and electrolyte imbalances such as hyperkalemia and hyperphosphatemia. Impaired urinary excretion of potassium may induce generalized skeletal muscle weakness, decrease myocardial excitability, increase myocardial refractory period and slow conduction. These may cause life-threatening cardiac arrhythmias [6] and require emergency treatment in several occasions [13, 21].

Surgical intervention is often required if obstruction does not resolve within 24–48 hr of medical management or if the cat shows signs of progressive hydronephrosis [5, 13, 16, 19, 20]. As an alternative to traditional surgical interventions for treatment of ureteral obstruction, the use of a subcutaneous ureteral bypass (SUB) device has been reported in cats [6, 13, 17]. The procedure is based on a locking loop kidney catheter and a fenestrated/cuffed bladder catheter that are both connected via subcutaneous tissue by a shunting port which allows the urine to flow directly from the kidney to the bladder, bypassing the ureter [7, 13]. Long-term success rates of SUBs in feline patients with ureteral obstruction have been reported. Reobstruction rate was 7% in patients treated with SUB whereas patients treated with a ureteral stent had a 19% reoccurrence [13]. Management and complications of anesthesia in cats undergoing surgical correction of ureteral obstruction has been reported [14]. However similar information has not been published specifically for SUB device placement. The aims of this study were to describe the management of anesthesia, and to report perioperative complications in cats undergoing SUB placement due to ureteral obstruction in a veterinary teaching hospital.

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Table 1. Demographic data of cats undergoing subcutaneous ureteral bypass placement in a veterinary teaching hospital for the treatment of ureteral obstruction

	Number of cats	Percentage (%)	Median (range)
Age (years)			7.8 (2.5–17.2)
Gender			
Male neutered	9	33.3	
Female neutered	18	66.7	
Weight (kg and lb)			4.1 (2.4–6.7) and 9.0 (5.3–14.7)
Breed			
Domestic	22	81.5	
Pure breeds[a)]	5	18.5	

a) Balinese (n=1), Burmese (n=1), Siamese (n=2), Tonkinese (n=1).

MATERIALS AND METHODS

Medical records of client-owned cats with ureteral obstruction presented to the Faculty of Veterinary Medicine, Université de Montréal, and undergoing unilateral or bilateral SUB placement, between April 2012 (earliest case) and September 2015, were reviewed in a retrospective manner. Exclusion criteria included incomplete anesthetic records and cats with concomitant, uncontrolled disease and unrelated to kidney failure (i.e. uncontrolled diabetes or hyperthyroidism, hypertrophic cardiomyopathy, etc.). Data collected included demographic information and abnormal findings for obtained from pre-anesthetic physical examination, hematology, biochemistry profile, urinalysis, blood pressure assessed with a portable oscillometric device (PetMAP™ 7120-0001 blood pressure measurement device, 2009), echocardiography, radiographs and ultrasonography examination. In the preoperative period, hypotension was defined as MAP (mean arterial pressure) ≤60 mmHg whereas hypertension was defined as SAP ≥140 mmHg. Anemia was arbitrarily defined as hematocrit (Ht) <28%. Other information of interest included American Society of Anesthesiologists (ASA) status [1], drugs administered, duration of surgery (from first incision to last suture) and anesthesia (from induction of anesthesia until turning the vaporizer off), days to discharge and perioperative complications. The ASA status was assigned by the anesthesiologist in charge of the case.

All cats were preoxygenated using a facemask between 3 and 5 min before anesthetic induction. Heart rate (HR) and rhythm during anesthesia were monitored continuously by use of a lead II electrocardiogram (ECG) tracing. Bradycardia and tachycardia were defined as HR ≤100 and ≥200 bpm, respectively, recorded for a minimum of 10 min in the anesthetic record. Invasive blood pressure (IBP) was used to continuously monitor systolic arterial pressure (SAP), MAP and diastolic arterial blood pressure (DAP). For IBP, the zero-reference point of the pressure transducer was set at the level of the right atrium. Doppler ultrasound assessing non-invasive blood pressure (NIBP) was used to monitor SAP if IBP was not available. For NIBP, the cuff was placed around the antebrachium and its width was approximately 40% of the circumference of the limb. Hypotension was defined either as SAP ≤80 mmHg or MAP ≤60 mmHg, or as SAP ≤60 mmHg for IBP or NIBP, respectively, recorded for at least 10 min. Hypertension was defined either as SAP ≥160 mmHg or MAP ≥100 mmHg recorded for at least 10 min. Temperature was recorded with an esophageal probe during anesthesia and using a digital thermometer inserted into the rectum during the postoperative period; values used for defining hypothermia and hyperthermia were ≤36.5 and ≥39.5°C, respectively. End-tidal CO_2 (P_{ETCO_2}) was evaluated using side-stream capnography. Hyper or hypocapnia was defined as P_{ETCO_2} ≥45 or ≤30 mmHg, respectively, for at least 10 min. Peripheral capillary oxygen saturation (SpO_2) was monitored with a pulse oximeter attached to the cat's tongue. Desaturation was defined as ≤94% recorded at any time point. Arterial blood samples were collected for blood gas analysis at the discretion of the anesthesiologist in charge. Hypoxemia was defined as partial pressure of oxygen in arterial blood (PaO_2) ≤70 mmHg. Postoperative complications were recorded for up to 48 hr following patient extubation. Nausea was considered a complication if the cat showed any of the following: ptyalism, retching, and/or vomiting. Pre- and post-anesthetic biochemistry profile and hematology were defined as the last values measured before induction of anesthesia and before discharge or re-induction of anesthesia (if a second surgery was necessary), respectively.

Data were verified for normality using a Shapiro-Wilk test. A paired *t*-test was used to compare serum creatinine, potassium, Ht and total solids (TS) before and after SUB placement. The association of potential risk factors (age, ASA status, duration of anesthesia, duration of surgery, and blood pressure and HR during surgery) with outcome variables (days to discharge and post-anesthesia creatinine) was evaluated using univariable analysis and Pearson correlation coefficients for quantitative data and Welch's *t*-tests (unequal variances *t*-tests) or analysis of variance tests were performed for categorical data as appropriate. Significance was set at $P \leq 0.05$.

RESULTS

Twenty-seven cats were considered for this study, all of which met the inclusion criteria. Seven cats required bilateral SUB placement. Demographic data and relevant physical findings are summarized in Table 1. Physical examination upon admission revealed a heart murmur (Levine grade ranging from I/VI to III/VI) in 16 cats (Table 1). Echocardiography findings showed that

Table 2. Preoperative assessment and intraoperative complications of cats undergoing subcutaneous ureteral bypass placement in a veterinary teaching hospital for the treatment of ureteral obstruction. Percentages are calculated based on a total of 27 cats.

	Findings	Number of cats (%)	Median (range)
Pre-anesthetic blood analysis	Serum creatinine (μmol/*l*)		295 (145–2,800)
	Serum potassium (mmol/*l*)		4.18 (2.70–6.27)
	Hematocrit (%)		28 (13–36)
	Total solids (g/*l*)		70 (52–88)
Abdominal ultrasound findings	Obstructive ureterolithiasis	15 (55.6)	
	Non-obstructive ureterolithiasis	5 (18.5)	
	Obstructive material (other than uroliths)	2 (7.4)	
	Ureteral stenosis	2 (7.4)	
	Cause of obstruction undetermined	8 (29.6)	
	Hydronephrosis	14 (51.8)	
	Nephroliths/parenchymal mineralization	11 (40.7)	
	Kidney atrophy	2 (7.4)	
	Pyelectasis	17 (63.0)	
	Material in bladder	8 (29.6)	
	Suspicion of pyelonephritis	4 (14.8)	
Distribution of obstruction	Left ureter	9 (33.3)	
	Right ureter	11 (40.7)	
	Bilateral	7 (25.9)	
ASA status	II	2 (7.4)	
	III	17 (63.0)	
	IV	5 (18.5)	
Intraoperative complications	Hypothermia	25 (92.6)	
	Hypotension	22 (81.5)	
	Hypocapnia	21 (77.8)	
	Hypertension	14 (51.8)	
	Bradycardia	13 (48.1)	
	Tachycardia	11 (40.7)	
	Light depth of anesthesia	11 (40.7)	
	Desaturation	5 (18.5)	

one cat was diagnosed with left posterior papillary muscle malformation and mitral valve dysplasia associated with low mitral regurgitation, and one with mild tricuspid regurgitation and right auricular dilation associated with fluid administration. One cat had feline asthma and was under treatment with fluticasone. These cats were included in the retrospective analysis.

Preoperative values are shown in Table 2. The majority of cats were azotemic (creatinine >180 μmol/*l* [2.0 mg/d*l*]; n=22), and 14 cats were anemic. Four cats required the administration of red blood cells due to severe anemia. Sixteen patients had their serum phosphorus assessed before anesthesia (median: 2.5 mmol/*l*; range: 0.9 to >5.2 mmol/*l*), and 11 had hyperphosphatemia (reference interval 0.96 to 1.96 mmol/*l*).

The duration of anesthesia and surgery (mean ± standard deviation) were 215 ± 42 min and 148 ± 36 min, respectively. Other surgical procedures during the same anesthetic episode included placement of an esophageal tube (n=2), cystoscopy (n=2), intestinal biopsies (n=1), liver biopsies (n=1), and percutaneous cystolithotomy (n=3). Intraoperative complications are described in Table 2. Five of the fourteen cats that showed hypertension during general anesthesia were also hypertensive upon admission. Hypotension was treated either with dobutamine (1–4 μg/kg/min), dopamine (5–15 μg/kg/min), ephedrine (0.05–0.1 mg/kg) or phenylephrine (0.1–0.2 μg/kg/min).

Anesthetic and analgesic drugs are listed in Table 3. Local anesthetic techniques included epidural, incisional line block, intraperitoneal (IP) block, or a combination of these techniques; six cats did not receive any local anesthetics. Lidocaine (1 mg/kg) was administered by the intravenous route in two cats during surgery due to high sympathetic tone and surgical stimulation [27]. Postoperative pain was managed using a constant rate infusion (CRI) of opioid, either fentanyl (n=22) or remifentanil (n=3), followed by buccal or intravenous buprenorphine. In the postoperative period, one cat was administered intravenous hydromorphone every 4 hr instead of an opioid CRI, and one cat received only buprenorphine. A fentanyl patch was placed in two cats in addition to the fentanyl CRI, one of which also had a dexmedetomidine CRI due to aggression; and one cat had a dexmedetomidine CRI in addition to remifentanil.

None of the cats died in the first 48 hr after surgery. The most common complications were pain (n=11), anorexia and/or nausea (n=8), hypo or hypertension (n=1 and n=7, respectively), dysphoria (n=5), and urinary tract-related problems such as hematuria or dysuria (n=5). Only three of the seven cats that showed hypertension after general anesthesia were hypertensive upon admission.

Table 3. Drugs and supportive therapy that were administered for the anesthetic and analgesic management, and maintenance of homeostasis in cats undergoing subcutaneous ureteral bypass placement in a veterinary teaching hospital

Therapy	Number of cats	Percentage (%)
Pre-anesthetic medication		
Buprenorphine	1	3.7
Fentanyl	5	18.5
Hydromorphone	10	37.0
Hydromorphone + acepromazine	2	7.4
Hydromorphone + alfaxalone	1	3.7
Hydromorphone + midazolam	2	7.4
Hydromorphone + midazolam + dexmedetomidine	1	3.7
Butorphanol + midazolam	1	3.7
Fentanyl + midazolam	2	7.4
Fentanyl + acepromazine	1	3.7
Remifentanil + midazolam	1	3.7
Induction		
Alfaxalone	8	29.6
Propofol	10	37.0
Alfaxalone + midazolam	3	11.1
Propofol + midazolam	5	18.5
Propofol + midazolam + ketamine	1	3.7
Fluid therapy		
Lactated Ringer's solution	22	81.5
Plasmalyte	4	14.8
Saline with dextrose 2.5%	1	3.7
Addition of KCl	2	7.4
Addition of whole blood transfusion	4	14.8
Addition of colloids	10	37.0
Maintenance		
Isoflurane	5	18.5
Isoflurane + fentanyl[a)]	18	66.7
Isoflurane + fentanyl[a)] + dexmedetomidine[a)]	1	3.7
Isoflurane + remifentanil[a)]	1	3.7
Isoflurane + remifentanil[a)] + ketamine[a)]	1	3.7
Sevoflurane + fentanyl	1	3.7
Local anesthesia		
Epidural	2	7.4
Intraperitoneal (IP) block	5	18.5
Incisional block	4	14.8
Epidural + IP	1	3.7
Epidural + incisional line block	6	22.2
Treatment of hypotension		
No inotrope	10	37.0
Dobutamine[a)]	7	25.9
Dopamine[a)]	10	37.0
Ephedrine	3	11.1
Phenylephrine[a)]	3	11.1
Glycopyrrolate	7	25.9

a) Administered as a constant rate infusion.

Electrolytic imbalances were recorded in two cats: one had hypokalemia (value <3.6 mmol/*l*) and the other had hypocalcemia (value <2.17 mmol/*l*). Two cats had partial obstruction of their SUB device, which resolved when flushed. Cats were discharged [median (range)] 2 (1–9) days after surgery. One cat was diagnosed with uroabdomen one week after bilateral SUB placement and had to undergo a second surgery for replacement of the left SUB; it was discharged 8 days after the first surgery.

There was a significant decrease in creatinine (P=0.008) and TS (P=0.007) after SUB placement, with a decrease in value (mean ± standard deviation) of 291 ± 502 μmol/*l* and 21 ± 7 g/*l*, respectively. The mean values for serum potassium and Ht were lower after surgery; however, the difference between pre and postoperative values were not statistically significant (P=0.33 and P=0.12, respectively).

Age, ASA status, duration of anesthesia, duration of surgery, blood pressure and heart rate during surgery were not significantly

correlated to the postoperative creatinine nor to the number of days to discharge ($P>0.05$). The use of a local anesthesia technique did not affect postoperative creatinine nor days to discharge ($P>0.05$). The use of IP analgesia seemed to decrease the number of days to discharge (2.2 days versus 2.9 days for cats with no IP analgesia), however the difference was not statistically significant ($P=0.25$).

DISCUSSION

This study described the management of anesthesia and perioperative complications in cats undergoing SUB placement in a veterinary teaching institution. These animals were admitted with concomitant cardiovascular abnormalities, pain and electrolyte imbalances which may impact anesthesia [8]. Anemia was observed in some cats which may result in decreased tissue oxygen delivery owing to associated decreases in arterial oxygen content. This may induce a rightward shift of the oxyhemoglobin dissociation curve and increased cardiac output as a reflection of decreased blood viscosity [28]. Anemia was considered to be severe in four cases and the administration of red blood cells was needed to avoid the aforementioned consequences. In addition, anesthetists should be cautious with excessive administration of crystalloids which may further decrease hemoglobin concentrations. Hemodilution may have occurred in some cats since TS were significantly decreased after surgery, and Ht values were also lower in the postoperative when compared with the preoperative period. On the other hand, postoperative decreases in creatinine values were expected due to the administration of fluid therapy and the nature of the condition where lower urinary tract outflow is re-established after surgery. Azotemia and uremia may have induced anorexia and nausea in the perioperative period.

Some cat breeds might be predisposed to calcium oxalate uroliths or struvite uroliths [23]; however, none of these breeds were represented in our study. A recent study [23] showed that neutered cats and cats older than four years of age were at higher risk of developing one or the other type of uroliths which is in accordance to our demographic data.

Hypothermia was the most common intraoperative complication. Hypotension, hypocapnia, hypertension and bradycardia were also frequently observed. A similar retrospective study [14] also found hypothermia to be the most common intraoperative complication in cats presented for correction of ureteral obstruction (86.5% of cases). In that study [14], hypothermia was correlated with prolonged duration of anesthesia. Such correlation could not be found in our study but it reflects how hypothermia is common in cats, a species with a large surface area in relation to body weight. Low body temperatures should be prevented and treated by using various heating methods (i.e. passive and active surface rewarming, and active core rewarming) [2] since hypothermia can lead to arrhythmias, coagulopathies and reduced oxygen delivery to tissue, among other negative effects [11]. Prevalence of hypothermia in cats has been associated with duration of anesthesia, the reason for anesthesia (abdominal versus orthopedic surgery) and the anesthetic risk (high-risk cats show lower temperature than low-risk cats) [25]. The same aforementioned study reported intraoperative hypotension (40.5%) and bradycardia (21.6%) as common complications during anesthesia [14]. However, in the present study, the prevalence of hypotension (81.5%) and bradycardia (48.1%) were greater and it may reflect our patient population, anesthetic and analgesic protocols, methods of blood pressure monitoring and different cut-offs to define these complications. For example, IBP monitoring was not used in the previous study [14], and the cut-off for bradycardia was different (HR <80, and not 100 beats/min). Opioid-induced vagal tone and hypothermia are common causes of bradycardia which in turn might induce hypotension, especially if one considers preoperative dehydration plus peripheral vasodilation and reductions in myocardial contractility during inhalant anesthesia. Some cats had cardiac changes that could lead to deleterious cardiovascular effects during anesthesia. Therefore, these issues (bradycardia and hypotension) were not surprising and highlight the need of judicious anesthetic monitoring, fluid therapy and early treatment of intraoperative complications. Inotropes and vasopressors were administered in order to provide cardiovascular support by increasing myocardial contractility, hemoglobin concentrations, and oxygen delivery [24]. Hypocapnia might have been the result of dilution of the carbon dioxide within the gas sample when using high-fresh gas flows in non-rebreathing systems. This should not be considered a true complication but most of these cats did not have a blood gas analysis to corroborate this hypothesis. On the other hand, intraoperative pain may induce tachypnea and hypocapnia as observed in some cats during light depth of anesthesia.

Postoperative complications included pain, anorexia, nausea, hypertension, and urinary tract-related problems. The prevalence of postoperative complications for feline ureteral obstruction correction varies among studies according to the surgical procedure, definition of the postoperative period (ranging from 48 hr after extubation to up to one month after surgery), and objective classification/reporting of postoperative complications. Postoperative complications were not life-threatening or unexpected in the present study. In fact, mortality in the post-operative period was not observed in our study and it is difficult to make any comparisons with previous studies that did not look at the anesthetic management and complications of patients with similar conditions. For example, perioperative anesthetic management of ureteral obstruction in cats in a teaching hospital [14] showed a mortality rate of 18.9%; however, only 14 cases had SUB placement, two of which died within 48 hr following surgery (Mateo A. G. C., personal communication). The difference between these two studies could be partially explained by patient population, severity of disease, perioperative medical management and anesthetic protocols. High serum creatinine in the preoperative period was considered to be a risk factor in the previous study [14]. Statistical analysis in this study could not identify risk factors.

One of the most important outcomes in this study was related to the prevalence of pain in the perioperative period. With a prevalence of over 40% as a postoperative complication, this study showed that pain should be properly assessed and aggressively treated in these cats. Balanced anesthesia and multimodal analgesia were incorporated in the anesthetic protocols in an attempt to minimize cardiorespiratory depression while maximizing pain relief [15, 18, 30]. Opioids were administered for analgesia and to decrease inhalant anesthetic concentrations by 15–20% [30]. Nonsteroidal anti-inflammatory drugs were not used because of their potential adverse effects in cases of renal impairment [22]. The majority (78%) of cats received a local anesthetic block at some

point during surgery. A trend towards the decrease in hospitalization time was observed with the use of the IP technique which was not significantly, but could be clinically relevant to an individual cat while reducing stress and costs with hospitalization. IP administration of bupivacaine has shown to be safe and to provide postoperative analgesia in cats undergoing OVH [3, 4], and it has been made part of the standard analgesic protocol for SUB placement at the authors' institution. In human medicine, many studies have reported the benefits of local anesthetics to reduce risk factors associated with morbidity or to accelerate recovery [9]. Epidural analgesia reduces the risks of venous thromboembolism, myocardial infarction, bleeding complications, pneumonia, respiratory depression, and renal failure [26], and provides faster rehabilitation after knee surgery [29]; femoral nerve block produces effective analgesia and hastens recovery after knee surgery [10, 31]. To the authors' knowledge, the association between the administration of local anesthetic blocks and hospitalization time or risk factors in feline patients has not been evaluated but one could speculate that local anesthetic techniques might reduce risk factors and time to hospital discharge.

This study has several limitations which include small sample size, the lack of different centers such as in a multi-center trial, absence of a case-control group undergoing a different surgical or anesthetic procedure, and its retrospective design. Using a larger cohort, perhaps the authors would have been able to identify risk factors and patient outcome, or the impact of the analgesic/anesthetic protocol in hastening recovery.

Successful management of anesthesia for SUB placement involves rigorous anesthetic monitoring and immediate treatment of complications. Perioperative complications appear to be common and include hypothermia, hypotension, bradycardia, hypocapnia, among others. Pain management should be properly addressed with the administration of opioid infusions and local anesthetic blocks, among other analgesic techniques. This study could not identify anesthetic-related risk factors associated with the SUB procedure.

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REFERENCES

1. American Society of Anesthesiologists website. 2014. ASA physical status classification system. Available at: http://www.asahq.org/resources/clinical-information/asa-physical-status-classification-system [accessed Aug 12, 2015].
2. Armstrong, S. R., Roberts, B. K. and Aronsohn, M. 2005. Perioperative hypothermia. *J. Vet. Emerg. Crit. Care.* **15**: 32–37. [CrossRef]
3. Benito, J., Monteiro, B. P., Beaudry, F., Lavoie, A. M., Lascelles, B. D. and Steagall, P. V. 2016. Pharmacokinetics of bupivacaine after intraperitoneal administration to cats undergoing ovariohysterectomy. *Am. J. Vet. Res.* **77**: 641–645. [Medline] [CrossRef]
4. Benito, J., Monteiro, B., Lavoie, A. M., Beauchamp, G., Lascelles, B. D. and Steagall, P. V. 2016. Analgesic efficacy of intraperitoneal administration of bupivacaine in cats undergoing ovariohysterectomy. *J. Feline Med. Surg.* **18**: 906–912. [CrossRef]
5. Berent, A. 2014. New techniques on the horizon: interventional radiology and interventional endoscopy of the urinary tract ('endourology'). *J. Feline Med. Surg.* **16**: 51–65. [Medline] [CrossRef]
6. Berent, A. C. 2011. Ureteral obstructions in dogs and cats: a review of traditional and new interventional diagnostic and therapeutic options. *J Vet Emerg Crit Care (San Antonio)* **21**: 86–103. [Medline] [CrossRef]
7. Berent, A. C. and Weisse, C. 2011. The SUB: a subcutaneous ureteral bypass system, a surgical guide. www.norfolkvetproducts.com [accessed July 21, 2016].
8. Bille, C., Auvigne, V., Libermann, S., Bomassi, E., Durieux, P. and Rattez, E. 2012. Risk of anaesthetic mortality in dogs and cats: an observational cohort study of 3546 cases. *Vet. Anaesth. Analg.* **39**: 59–68. [Medline] [CrossRef]
9. Boddy, A. P., Mehta, S. and Rhodes, M. 2006. The effect of intraperitoneal local anesthesia in laparoscopic cholecystectomy: a systematic review and meta-analysis. *Anesth. Analg.* **103**: 682–688. [Medline] [CrossRef]
10. Capdevila, X., Barthelet, Y., Biboulet, P., Ryckwaert, Y., Rubenovitch, J. and d'Athis, F. 1999. Effects of perioperative analgesic technique on the surgical outcome and duration of rehabilitation after major knee surgery. *Anesthesiology* **91**: 8–15. [Medline] [CrossRef]
11. Clark-Price, S. 2015. Inadvertent perianesthetic hypothermia in small animal patients. *Vet. Clin. North Am. Small Anim. Pract.* **45**: 983–994. [Medline] [CrossRef]
12. Dal Canton, A., Corradi, A., Stanziale, R., Maruccio, G. and Migone, L. 1979. Effects of 24-hour unilateral ureteral obstruction on glomerular hemodynamics in rat kidney. *Kidney Int.* **15**: 457–462. [Medline] [CrossRef]
13. Defarges, A., Berent, A. and Dunn, M. 2013. New alternatives for minimally invasive management of uroliths: ureteroliths. *Compend Contin Educ Vet* **35**: E4. [Medline]
14. Garcia de Carellan Mateo, A., Brodbelt, D., Kulendra, N. and Alibhai, H. 2015. Retrospective study of the perioperative management and complications of ureteral obstruction in 37 cats. *Vet. Anaesth. Analg.* **42**: 570–579. [Medline] [CrossRef]
15. Gutierrez-Blanco, E., Victoria-Mora, J. M., Ibancovichi-Camarillo, J. A., Sauri-Arceo, C. H., Bolio-González, M. E., Acevedo-Arcique, C. M., Marin-Cano, G. and Steagall, P. V. 2013. Evaluation of the isoflurane-sparing effects of fentanyl, lidocaine, ketamine, dexmedetomidine, or the combination lidocaine-ketamine-dexmedetomidine during ovariohysterectomy in dogs. *Vet. Anaesth. Analg.* **40**: 599–609. [Medline] [CrossRef]
16. Hardie, E. M. and Kyles, A. E. 2004. Management of ureteral obstruction. *Vet. Clin. North Am. Small Anim. Pract.* **34**: 989–1010. [Medline] [CrossRef]
17. Horowitz, C., Berent, A., Weisse, C., Langston, C. and Bagley, D. 2013. Predictors of outcome for cats with ureteral obstructions after interventional management using ureteral stents or a subcutaneous ureteral bypass device. *J. Feline Med. Surg.* **15**: 1052–1062. [Medline] [CrossRef]
18. Kehlet, H. and Dahl, J. B. 1993. The value of "multimodal" or "balanced analgesia" in postoperative pain treatment. *Anesth. Analg.* **77**: 1048–1056. [Medline]
19. Kulendra, N. J., Syme, H., Benigni, L. and Halfacree, Z. 2014. Feline double pigtail ureteric stents for management of ureteric obstruction: short- and long-term follow-up of 26 cats. *J. Feline Med. Surg.* **16**: 985–991. [Medline] [CrossRef]
20. Kyles, A. E., Hardie, E. M., Wooden, B. G., Adin, C. A., Stone, E. A., Gregory, C. R., Mathews, K. G., Cowgill, L. D., Vaden, S., Nyland, T. G. and Ling, G. V. 2005. Management and outcome of cats with ureteral calculi: 153 cases (1984–2002). *J. Am. Vet. Med. Assoc.* **226**: 937–944. [Medline]

[CrossRef]
21. Kyles, A. E., Hardie, E. M., Wooden, B. G., Adin, C. A., Stone, E. A., Gregory, C. R., Mathews, K. G., Cowgill, L. D., Vaden, S., Nyland, T. G. and Ling, G. V. 2005. Clinical, clinicopathologic, radiographic, and ultrasonographic abnormalities in cats with ureteral calculi: 163 cases (1984-2002). *J. Am. Vet. Med. Assoc.* **226**: 932–936. [Medline] [CrossRef]
22. Lascelles, B. D. X., Court, M. H., Hardie, E. M. and Robertson, S. A. 2007. Nonsteroidal anti-inflammatory drugs in cats: a review. *Vet. Anaesth. Analg.* **34**: 228–250. [Medline] [CrossRef]
23. Lekcharoensuk, C., Lulich, J. P., Osborne, C. A., Koehler, L. A., Urlich, L. K., Carpenter, K. A. and Swanson, L. L. 2000. Association between patient-related factors and risk of calcium oxalate and magnesium ammonium phosphate urolithiasis in cats. *J. Am. Vet. Med. Assoc.* **217**: 520–525. [Medline] [CrossRef]
24. Pascoe, P. J., Ilkiw, J. E. and Pypendop, B. H. 2006. Effects of increasing infusion rates of dopamine, dobutamine, epinephrine, and phenylephrine in healthy anesthetized cats. *Am. J. Vet. Res.* **67**: 1491–1499. [Medline] [CrossRef]
25. Redondo, J. I., Suesta, P., Gil, L., Soler, G., Serra, I. and Soler, C. 2012. Retrospective study of the prevalence of postanaesthetic hypothermia in cats. *Vet. Rec.* **170**: 206. [Medline] [CrossRef]
26. Rodgers, A., Walker, N., Schug, S., McKee, A., Kehlet, H., van Zundert, A., Sage, D., Futter, M., Saville, G., Clark, T. and MacMahon, S. 2000. Reduction of postoperative mortality and morbidity with epidural or spinal anaesthesia: results from overview of randomised trials. *BMJ* **321**: 1493. [Medline] [CrossRef]
27. Schubert, A., Licina, M. G., Glaze, G. M. and Paranandi, L. 1992. Systemic lidocaine and human somatosensory-evoked potentials during sufentanil-isoflurane anaesthesia. *Can. J. Anaesth.* **39**: 569–575. [Medline] [CrossRef]
28. Shepard, M. and Brainard, B. 2015. Hematologic disorders. pp. 203–222. *In*: Canine and Feline Anesthesia and co-existing disease, 1st ed. (Snyder, L. C. and Johnson, R. A. eds.), Wiley-Blackwell, Ames.
29. Singelyn, F. J., Deyaert, M., Joris, D., Pendeville, E. and Gouverneur, J. M. 1998. Effects of intravenous patient-controlled analgesia with morphine, continuous epidural analgesia, and continuous three-in-one block on postoperative pain and knee rehabilitation after unilateral total knee arthroplasty. *Anesth. Analg.* **87**: 88–92. [Medline]
30. Steagall, P. V. M., Aucoin, M., Monteiro, B. P., Moreau, M., Simon, B. T. and Burns, P. M. 2015. Clinical effects of a constant rate infusion of remifentanil, alone or in combination with ketamine, in cats anesthetized with isoflurane. *J. Am. Vet. Med. Assoc.* **246**: 976–981. [Medline] [CrossRef]
31. Wang, H., Boctor, B. and Verner, J. 2002. The effect of single-injection femoral nerve block on rehabilitation and length of hospital stay after total knee replacement. *Reg. Anesth. Pain Med.* **27**: 139–144. [Medline]