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.
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 CO2 (PETCO2) was evaluated using side-stream capnography. Hyper or hypocapnia was defined as PETCO2 >45 or ≤30 mmHg, respectively, for at least 10 min. Peripheral capillary oxygen saturation (SpO2) 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 (PaO2) ≤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: ptalism, 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<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
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; 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.
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

### Table 3

| 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 | 18 | 66.7 |
| Isoflurane + fentanyl + dexmedetomidine | 1 | 3.7 |
| Isoflurane + remifentanil | 1 | 3.7 |
| Isoflurane + remifentanil + ketamine | 1 | 3.7 |
| Sevoflurane + fentanyl | 1 | 3.7 |
| Local anesthesia |               |                |
| Epidural | 2 | 7.4 |
| Intrapерitoneal (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 | 7 | 25.9 |
| Dopamine | 10 | 37.0 |
| Ephedrine | 3 | 11.1 |
| Phenylephrine | 3 | 11.1 |
| Glycopyrrolate | 7 | 25.9 |

a) Administered as a constant rate infusion.
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 warming, and active core warming) [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 for 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
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