Evaluation of urodynamic procedures in female cats anesthetized with low and high doses of isoflurane and propofol

Todd A. Cohen, DVM; Jodi L. Westropp, DVM, PhD; Philip H. Kass, DVM, PhD; Bruno H. Pypendop, DrMedVet, DrVetSci

Objective—To compare effects of isoflurane and propofol on the cystometrogram and urethral pressure profile (UPP) in healthy female cats.

Animals—6 healthy female cats.

Procedures—Cats were anesthetized, and a consistent plane of anesthesia was maintained with low and high doses of isoflurane and propofol. A 6-F double-lumen urinary catheter was placed aseptically in the urethra for cystometrogram and UPP measurements. Threshold pressure and volume were recorded for cystometrograms. Maximum urethral pressure for smooth and skeletal muscle portions of the urethra, maximum urethral closure pressure, and functional profile length were measured during each UPP measurement. Heart rate and respiratory rate were recorded.

Results—Cats anesthetized with the low dose of propofol had consistent detrusor reflexes, compared with results for the other anesthetics. Mean ± SD threshold pressure, volume per unit of body weight, and compliance were 75.7 ± 16.3 cm H_2O, 8.3 ± 3.2 mL/kg, and 0.5 ± 0.4 mL/cm H_2O, respectively, for low-dose propofol. Anesthesia with either dose of propofol caused a significantly higher percentage change in heart rate during the cystometrogram, compared with results for anesthesia with isoflurane. Maximal urethral pressure in the area corresponding to skeletal muscle and the maximum urethral closure pressure were significantly higher for the low dose of propofol, compared with results for the high dose of propofol.

Conclusions and Clinical Relevance—The low-dose propofol regimen was the easiest to titrate and maintain and yielded diagnostic-quality detrusor reflexes in all 6 cats. Anesthetic depth should be titrated appropriately when performing urodynamic procedures. (*Am J Vet Res* 2009;70:290–296)

Urodynamic procedures, including UPPs and cystometrograms, are useful diagnostic tools in small animals to investigate function of the urethra and urinary bladder as well as to evaluate the response of these organs to various treatments.[1–4] In the past, equipment necessary to perform urodynamic studies in small animals was usually available at only a few referral facilities; however, more institutions currently have the necessary equipment to perform these diagnostic tests. Protocols for performing UPPs and cystometrograms in dogs have been published.[5,6] According to these studies, UPPs can be performed in dogs by use of low doses of propofol or sevoflurane, and these protocols have also been used to evaluate dogs with urethral sphincter mechanism incompetence.[7] Although xylazine reportedly has little effect on the detrusor reflex,[8] cystometrograms have also been evaluated in dogs by use of propofol.[5] Although several studies have been published on these procedures in dogs, we are unaware of any published studies in which investigators evaluated the effects of anesthetics on these procedures in cats.

Urodynamic procedures could be used in cats to evaluate feline lower urinary tract disorders, such as feline idiopathic cystitis and urinary retention and incontinence caused by tail-pull injuries. Moreover, UPPs and cystometrograms are minimally invasive diagnostic tests that can be used to evaluate treatments and prognosis for animals with these problems. In humans, these diagnostic tests are routinely performed without sedation or anesthesia; however, it can be difficult to perform cystometrograms and UPPs in cats without adequate chemical restraint. Therefore, the objective of the study reported here was to evaluate the suitability

Abbreviations

FPL	Functional profile length
MUCP	Maximum urethral closure pressure
MUP	Mean urethral pressure
UPP	Urethral pressure profile

Received December 21, 2007.
Accepted May 7, 2008.
From the Departments of Medicine and Epidemiology (Cohen, Westropp), Population Health and Reproduction (Kass), and Surgical and Radiological Sciences (Pypendop), School of Veterinary Medicine, University of California, Davis, CA 95616.
Supported in part by a grant from the Center for Companion Animal Health at the University of California, Davis, and the Gucci Ferracone Fund for Feline Urinary Disease Research.
Presented in abstract form at the 25th Annual American College of Veterinary Internal Medicine Forum, Seattle, June 2007.
The authors thank Kristine Siao for technical assistance.
Address correspondence to Dr. Westropp.

of 2 commonly used anesthetic agents (each at 2 doses) for use in cats to obtain urodynamic measurements. We also evaluated heart rate and respiratory rate for each of the 4 anesthetic protocols.

Materials and Methods

Animals—Six healthy spayed female adult cats were used in the study. Cats were 4 to 9 years old (mean, 6.8 years) and weighed 4.0 to 7.2 kg (mean, 5.3 kg). All cats were housed at the Center for Laboratory Animal Sciences, University of California, Davis. Each cat was deemed healthy on the basis of results of a physical examination, CBC, biochemical analysis, urinalysis, and bacterial culture of urine sample. Cats included in the study had no signs of lower urinary tract disease, including (but not limited to) hematuria, stranguria, pollakiuria, dysuria, and periuria. Urine samples for bacterial culture were also obtained prior to the second set of urodynamic procedures to be certain that repeated catheterizations did not cause colonization of bacteria in the urinary tract. All experimental procedures were approved by the Animal Care and Use Committee of the University of California, Davis.

Anesthesia—Each cat was anesthetized twice (once by administration of inhalation anesthesia [ie, isoflurane] and once by administration of an injectable agent [ie, propofol]); 2 concentrations of each anesthetic (low dose and high dose) were used during each anesthetic episode. The order of the anesthetics was randomly assigned by use of a computer-generated random list, and there was a minimum washout period of 21 days between subsequent anesthetic procedures. Food was withheld from cats for 12 hours before each anesthetic procedure.

For the inhalant anesthesia protocol, anesthesia was induced in an induction chamber by administration of isoflurane[a] in oxygen. Once at an appropriate anesthetic depth, cats were intubated and anesthesia was maintained by administration of isoflurane in oxygen delivered via a nonrebreathing circuit, with a fresh gas flow of 250 mL/kg/min. Inspired and end-tidal oxygen, carbon dioxide, and isoflurane concentrations were continuously measured with a Raman spectrometer[b] that had been calibrated prior to each experiment by use of room air and 3 calibration gases that contained known concentrations of isoflurane. Moreover, prior to each urodynamic measurement, end-tidal isoflurane concentration was verified in a sample collected manually into a glass syringe. End-tidal isoflurane concentration was then measured with an infrared analyzer[c] calibrated prior to each experiment by use of room air and 3 calibration gases[d] that contained known concentrations of isoflurane. A Doppler crystal, occluding cuff, and sphygomanometer were used to measure systolic blood pressure and heart rate, respectively. Respiratory rate was obtained from the Raman spectrometer. Heart and respiratory rates were measured and recorded every minute for the cystometrograms and every 30 seconds during the UPPs. Body temperature was continuously measured in the esophagus by use of a thermistor that had been calibrated prior to each experiment by use of a certified thermometer. Each cat was randomly assigned to receive an end-tidal isoflurane concentration of 1.75% (low dose) or 2% (high dose), and at least 20 minutes was allowed for equilibration between alveolar and effect-site (ie, CNS) concentrations prior to beginning instrumentation for the urodynamic procedures. This time frame was based on similar data reported for dogs[6] as well as results of preliminary studies conducted on cats by our laboratory group. Two cystometrograms and 2 UPPs were performed at the isoflurane concentration. End-tidal isoflurane concentration was then set to the alternate concentration, and 20 minutes was allowed for equilibration prior to repeating the 2 cystometrograms and 2 UPPs.

For the injectable anesthesia protocol, a catheter was inserted into a vein and propofol[e] was administered to induce and maintain sedation and anesthesia. A bolus (2 mg/kg, IV) was administered, followed by a constant rate infusion of 0.2 mg/kg/min (low dose). Oxygen (2 L/min) was delivered via face mask because cats were deemed to be at an insufficient depth of anesthesia to tolerate tracheal intubation. Blood pressure and heart rate were measured as described for the inhalation protocol. Body temperature was measured every 10 minutes via the rectum by use of a rectal thermometer. Respiratory rate was measured by counting chest excursions. After infusion of propofol for 20 minutes to ensure equilibration, the urodynamic procedures were initiated. Two cystometrograms and 2 UPPs were then performed. After completion of the second UPP, an additional bolus of propofol (2 mg/kg, IV) was administered and the infusion rate was increased to 0.4 mg/kg/min (high dose). To minimize the time needed to complete the experiment, the order of propofol doses was always the low dose followed by the high dose and therefore not randomized. After administration of the high dose was started, cats were intubated and oxygen (250 mL/kg/min) was delivered via a nonrebreathing circuit. A thermistor, calibrated by use of a certified thermometer prior to each experiment, was inserted in the distal third of the esophagus for continuous measurement of body temperature. The Raman spectrometer was used to measure respiratory rate. Blood pressure and heart rate were measured as described for the inhalation protocol. After infusion of propofol for 20 minutes, the urodynamic procedures were repeated.

Urodynamic evaluations—All urodynamic procedures were performed by use of a commercially available system.[f] Once each cat had reached a stable plane of anesthesia, a 6-F double-lumen urinary catheter[g] was aseptically placed in the urethra and the bladder was emptied. The catheter was then connected to a pressure transducer for continuous measurement of intravesical pressure. Resting bladder pressure was recorded. Warm sterile water was then infused at a rate of 4 mL/min. The bladder was filled and pressures recorded until a detrusor reflex was detected. Threshold pressure and volume were recorded at the time the detrusor reflex was detected. Bladder compliance was calculated for each procedure as follows: amount of fluid infused/(bladder pressure – resting bladder pressure). The cystometrogram was performed twice to ensure that similar tracings were obtained. A mean value for the 2 replicates of each cat was calculated. When a strong, identifiable detrusor reflex was not obtained, threshold pressure could not be reported for that cat. Heart and respiratory rates were recorded every minute as well as at the time of bladder contraction or when the fluid passively leaked around the catheter when a detrusor reflex was not evident.

After completion of the cystometrogram, UPP measurements were obtained by use of the same 6-F double-lumen catheter used for the cystometrogram. The catheter was connected to pressure transducers to record intravesical pressure and urethral pressure along the functional length of the urethra. The catheter was placed so that the tip was immediately proximal to the bladder trigone. A 3-way stopcock was used on the urethral pressure port for simultaneous infusion of warm sterile water. The urethral catheter was mechanically withdrawn at a rate of 0.5 mm/s while sterile water was infused at a rate of 2 mL/min. The MUP was recorded for the areas corresponding to the smooth muscle and skeletal muscle portions of the urethra, as described elsewhere.[9] The MUCP was calculated by subtracting the resting bladder pressure from the MUP obtained in the portion of the urethra corresponding to skeletal muscle. The FPL was measured as the region of the tracing during which urethral pressure exceeded baseline perfusion pressure. Heart and respiratory rates were recorded every 30 seconds during the procedure. This procedure was also performed twice; a mean value for each of the 2 replicates of each cat was calculated.

Statistical analysis—For the urodynamic studies, a 2-way ANOVA was performed on the data. A natural logarithmic transformation was used for respiratory rate to ensure it was more in conformity with the normality assumption. Significance was defined as values of $P < 0.05$.

Results

Animals—All cats could be easily catheterized when anesthetized in accordance with each of the 4 anesthetic regimens; however, 2 cats required additional manual restraint (1 for low-dose propofol and 1 for low-dose isoflurane, respectively). This required that an assistant gently restrain the hind limbs so that aseptic technique could be used to catheterize the cat. No anesthetic complications were detected throughout the study. Furthermore, no problems were evident related to the urinary tract, including gross hematuria or urinary tract infections, for any of the urodynamic procedures. Pronounced artifact was obtained during several UPP evaluations; therefore, only those tracings that could be easily interpreted for evaluation were included in the study. When choosing tracings that yielded results considered adequate for evaluation, the principal investigator (JLW) was not aware of the anesthetic regimen used.

Cystometrograms—We did not detect significant differences between the first and second replicate for any of the variables analyzed, so the mean of the 2 replicates was used for each cat. No significant interactions among variables were found. All 6 cats had an identifiable detrusor reflex while anesthetized with the low dose of propofol, but only 2 of 6 cats had an extremely weak detrusor reflex, and the remaining 4 leaked urine passively around the catheter while anesthetized with the high dose of propofol. Three of 6 cats had an identifiable detrusor response while anesthetized with the low dose of isoflurane, and the remaining 3 had an extremely weak detrusor reflex. Only 1 of 6 cats had a definable detrusor reflex while anesthetized with the high dose of isoflurane, and 1 other cat had a subjectively extremely weak reflex. Threshold pressures, volume per unit of body weight, and compliance were calculated for each anesthetic regimen (**Table 1**). Cats had a significantly ($P = 0.036$) higher mean ± SD threshold pressure (75 ± 16.3 cm H_2O) while anesthetized with the low dose of propofol, compared with threshold pressure (46.3 ± 15.2 cm H_2O) while anesthetized with the low dose of isoflurane. No significant differences for total volume infused or compliance were found among anesthetic regimens.

Anesthesia with either dose of propofol caused a significantly ($P = 0.005$) higher percentage change in heart rate during the cystometrogram (mean ± SD, 17.5 ± 8.1%), compared with the change for anesthesia with isoflurane (2.0 ± 2.9%). Furthermore, anesthesia with the low dose of propofol or isoflurane caused a significantly ($P = 0.003$) higher heart rate at the end of the cystometrogram procedure (181 ± 12 beats/min), compared with the heart rate for anesthesia with the high dose of either drug (158 ± 7 beats/min). Cats had a higher, but not significantly ($P = 0.06$) different, respiratory rate when anesthetized with either dose of isoflurane (28 ± 11 breaths/min), compared with the respiratory rate for the cats anesthetized with propofol (18 ± 3 breaths/min). No significant differences in percentage

Table 1—Mean ± SD values for threshold pressure, volume infused per unit of body weight, and compliance for cats anesthetized by use of low and high doses of propofol and isoflurane and in which there was an identifiable detrusor reflex.

	Propofol*	Isoflurane	
Variable	Low dose (n = 6)	Low dose (n = 3)	High dose (n = 1)†
Threshold pressure (cm H_2O)	75.7 ± 16.3[a]	46.3 ± 15.2[b]	59.5
Total volume (mL/kg)	8.3 ± 3.2	3.8 ± 2.9	8.5
Compliance (mL/cm H_2O)	0.5 ± 0.4	0.7 ± 0.2	1.1

The low and high doses of propofol represented a steady-state condition achieved after a constant rate infusion of 0.2 mg/kg/min and 0.4 mg/kg/min, respectively. The low and high doses of isoflurane represented a steady-state condition achieved after administration of 1.75% and 2%, respectively.

*None of the cats had an identifiable detrusor reflex when anesthetized with the high dose of propofol. †Mean ± SD could not be calculated because only 1 cat had an identifiable detrusor reflex. [a,b]Within a row, values with different superscript letters were significantly (P< 0.05) different.

Table 2—Mean ± SD heart rate and respiratory rate while obtaining cystometrograms in 6 cats anesthetized by use of low and high doses of propofol and isoflurane.

Variable	Propofol		Isoflurane	
	Low dose	High dose	Low dose	High dose
Heart rate (beats/min)*	185 ± 26[a]	168 ± 16[b]	177 ± 29[a]	148 ± 16[b]
Increase in heart rate (%)†	17.0 ± 8.0[a]	18.0 ± 10.7[a]	2.8 ± 7.7[b]	1.2 ± 2.5[b]
Respiratory rate (breaths/min)*	26 ± 6	11 ± 3	36 ± 21	21 ± 14
Increase in respiratory rate (%)†	4.2 ± 19.1	24.8 ± 29.1	22.8 ± 29.0	12.7 ± 12.8

*Represents value determined at the time the detrusor reflex or urine leakage was detected. †Represents the percentage change during the cystometrogram procedure.
See Table 1 for remainder of key.

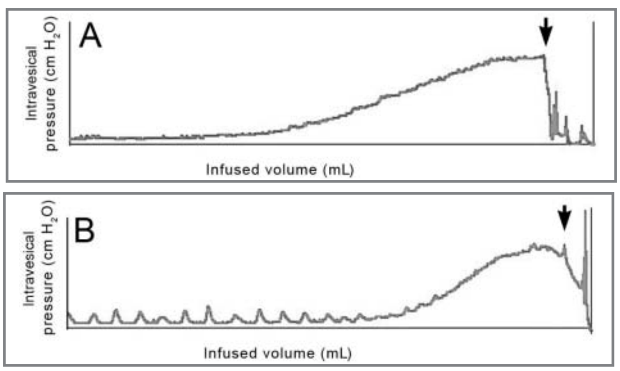

Figure 1—Tracings for a cystometrogram performed in a cat anesthetized with a low dose of propofol. In panel A, the detrusor reflex is indicated (arrow), and a measurement of 73 cm H_2O is identified as the threshold pressure. In panel B, notice the detrusor reflex (arrow) and the undulations in the baseline pressure, which were characteristic of undulations detected in all cats at various times throughout the experiments. These undulations are suggestive of idiopathic detrusor overactivity that does not result in clinical signs.

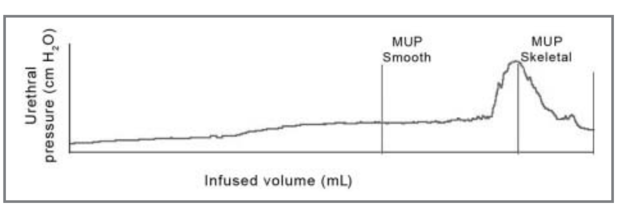

Figure 2—The UPP tracing obtained for a cat anesthetized with a high dose of propofol. The MUP corresponding to the smooth muscle and skeletal muscle portions of the urethra is indicated.

increase in respiratory rate were found among anesthetic regimens. Mean heart rate and respiratory rate were calculated for each anesthetic protocol (**Table 2**).

Undulations in the area of the tracing for which the bladder pressure was undergoing relaxation and compliance as the fluid was infused, which most often was detected after at least 1 cystometrogram was performed, were evident in all cats at various times during the study. Cystometrograms with normal results as well as those with fluctuations in the baseline pressure were identified (**Figure 1**).

UPPs—Five cats had UPPs that were evaluated statistically; all 5 of those measurements were obtained when cats were anesthetized with propofol. There were no significant differences between the first and second replicate for each variable analyzed (ie, MUP, MUCP,

Table 3—Mean ± SD values for MUP, MUCP, and FPL during UPP measurements performed in 6 cats anesthetized by use of low and high doses of propofol.

Variable	Low dose	High dose
MUP (cm H_2O)*		
Smooth	39.5 ± 7.2	38.7 ± 7.4
Skeletal	106.4 ± 25.1[a]	81.0 ± 22.3[b]
MUCP (cm H_2O)	88.9 ± 23.9[a]	64.5 ± 21.6[b]
FPL (cm)	5.6 ± 0.4	5.6 ± 0.4

*Represents values corresponding to the smooth and skeletal muscle portions of the urethra.
[a,b]Within a row, values with different superscript letters differ significantly ($P < 0.05$).
See Table 1 for remainder of key.

and FPL) for both the low and high doses of propofol, so the means of the 2 were used for each cat. The MUP was determined in the smooth and skeletal muscle portions where pressures were obtained (**Figure 2**). Significant differences were found for the MUP in the skeletal muscle portion, whereby it was significantly ($P = 0.022$) higher for the low dose of propofol, compared with results for the high dose of propofol (**Table 3**). Similarly, the MUCP was significantly ($P = 0.046$) higher in the UPPs performed when cats were anesthetized with the low dose of propofol, compared with results for those performed when cats were anesthetized with the high dose of propofol. Cats anesthetized with the low dose of propofol had a significantly ($P = 0.022$) higher percentage change in heart rate during the UPPs, compared with the percentage change in heart rate when cats were anesthetized with the high dose of propofol. Percentage increase in respiratory rate did not differ significantly ($P = 0.50$) among anesthetic regimens.

Discussion

In the study reported here, we established that urodynamic procedures could be performed in healthy female cats anesthetized with propofol or isoflurane. Each anesthetic protocol provided adequate chemical restraint, and there were no complications from the procedures in the 6 cats. However, use of the low-dose regimen of either drug required that minimal manual restraint be applied to some cats to enable us to perform the diagnostic tests.

The cystometrogram is a useful diagnostic tool to evaluate physiologic aspects of the bladder in states of health and disease and is used primarily in humans to evaluate patients for an overactive bladder,[10] a condition that can result in increased frequency of urination, urgency to urinate, and even incontinence. Cystometrograms allow investigators to evaluate the effects of drug regimens used for treating cats with various lower urinary tract disorders. Although cystometrograms have been used to study physiologic aspects of the bladder in cats,[11,12] the procedures and anesthetic protocols were not standardized and the clinical use of this diagnostic test in cats has not been adequately determined.

Spontaneous increases in pressure tracings of the cystometrogram in the region of the tracing for which the bladder pressure was undergoing relaxation and compliance as the fluid was infused were evident in most cats. The deflections were periodic undulations in the baseline pressures that sometimes developed as the pressure increased. Cats did not move, and these waves could not be attributed to respirations or the fluid pump. Therefore, these findings suggested spontaneous detrusor overactivity. Detrusor overactivity exists when there are involuntary detrusor contractions during the filling phase.[13] An overactive detrusor may not cause clinical signs and does not necessarily imply a neurologic disorder. These cats were clinically and biochemically normal with regard to their urinary tract, and it is likely these tracing abnormalities were idiopathic and of no clinical importance. It has been suggested[10] that there are varying clinical degrees of involuntary detrusor contractions in humans. Idiopathic detrusor overactivity is believed to be the most common form of this finding. To determine whether the increased pressure spikes are abnormal, it is necessary to ask the patient whether urgency or pain is associated with the findings on the cystometrogram; obviously, this was not possible when evaluating our cats. However, there was no urinary leakage when the undulations in the cystometrogram were detected, and the cats did not appear to be agitated. It is possible these findings were attributable to the filling rate that was used for the cystometrogram; a rate of 4 mL/min is considered a medium-high fill rate, as determined on the basis of information established by the International Continence Society for humans.[12] Although we knew this filling rate may be of concern, a lower rate was not used because the equipment used to perform these experiments did not allow calibration of the infusion pump to a lower setting. Although the fluid infusion may have contributed to detrusor overactivity, we also cannot rule out that repeated bladder distention may also have contributed to these findings.

Ideally, for proper statistical analysis, it would be preferable to obtain 3 cystometrograms and 3 UPPs for each cat. According to published information in human medicine,[14] repeated bladder distention may lead to an increase in physiologic and perceptual responses to pain; therefore, we limited the number of cystometrograms performed on each cat. A series of cystometrograms with medium or rapid filling rates can also lead to a gradual increase in bladder capacity, which is a phenomenon described in humans as hysterisis.[13]

Cystometrograms have been described in dogs, particularly in relation to investigations of various anesthetic protocols. In 1 study,[8] xylazine affected the detrusor reflex the least and provided the most consistent results in dogs. However, in that study, detrusor reflexes were detected only 39 of 60 times in dogs sedated with xylazine and only 27 of 60 times in dogs sedated with medetomidine. This diagnostic test has also been used with other anesthetic regimens[5] because of the pronounced bradycardia that can be encountered with an α_2-receptor agonist. Use of the low dose of propofol yielded the most consistent results in the cats we evaluated, compared with results for the other anesthetic regimens. Only 1 cat anesthetized with the high dose of isoflurane and no cats anesthetized with the high dose of propofol had an identifiable detrusor reflex that could be evaluated. Therefore, we cannot recommend these anesthetic protocols when performing cystometrograms in cats. Furthermore, it is possible that the MUCPs were lower in the high-dose drug regimens and allowed spontaneous passage of the sterile water during the cystometrogram. The MUCPs analyzed for cats anesthetized with the low and high doses of propofol supported this hypothesis.

Overall, we detected increases in heart rate as the cystometrograms were performed. When evaluating cardiovascular variables during the cystometrograms we performed, cats anesthetized with a low dose of propofol or a low dose of isoflurane had significantly higher heart rates at the time of detrusor reflex or urine leakage. Throughout every cystometrogram we performed, heart rate always appeared to increase prior to the detrusor reflex or urine leakage events. The same was not found for respiratory rate. Higher heart rates were detected with the low-dose protocols, which suggested that the cats were in a much lighter plane of anesthesia. Respiratory rates were slightly but not significantly lower for cats anesthetized with propofol, which likely reflected the profound respiratory depression that can be caused by administration of this drug.[15]

Similar to the findings with the cystometrograms performed during this study, the low doses of anesthetic agents resulted in higher urethral pressures generated within the skeletal muscle portion of the urethra. Therefore, the MUCP (which is a calculated value) was also higher with the low dose of propofol, which suggested that this dose had less effect on urethral tone. Although the propofol doses were not randomized, the differences were likely to be present, even though a longer anesthetic time cannot be ruled out. However, similar findings have been reported[6] for dogs when similar propofol protocols are used.

The clinical use of the UPP in cats has not been adequately described. Reports have been published on evaluation of the UPP in nonanethetized male cats[16] and female cats anesthetized by use of older equipment and administration of halothane.[9,17] The mean ± SD MUCP obtained for the low dose of propofol in the study reported here (88.9 ± 23.9 cm H_2O) was slightly higher than the mean MUCP obtained when investigators in another study[17] evaluated female cats (77.5 ± 31.3 cm H_2O). However, it is hard to make comparisons between other studies and the study reported here because those other studies were performed with different equipment, infusion rates, and anesthetics.

The objective of our study was to establish reference values and an appropriate anesthetic regimen for UPP measurements and cystometrograms in healthy female cats to provide a baseline for comparison in cats with lower urinary tract disease and to be able to compare studies from various institutions conducted by use of the same protocols and equipment. The small sample size and use of a single sex of cats posed some limitations for this study. We wanted to evaluate male cats as well; however, commercially available double-lumen urinary catheters small enough to use in a male cat are not currently available. We intend to evaluate other catheter options in the future and are currently investigating various double-lumen IV catheters for this procedure. Another limitation of our study was the lack of reliable UPP data for cats anesthetized with isoflurane at either concentration. Unfortunately, the UPPs performed in every cat anesthetized with either the low or high dose of isoflurane had such severe artifacts in the pressure tracings that accurate assessment of the results was impossible. The cats were randomly assigned to the drug protocols on the basis of results of a standard computer program; however, diagnostic tracings were only obtained from cats anesthetized with propofol. Although the protocols were randomly assigned, many cats were sequentially anesthetized with propofol. Retrospectively, the issue of unusable diagnostic tracings could have resolved as a result of new tubing or a dampening chamber that was implemented. Subsequent experiments with newer tubing have continuously provided reliable results.

Another limitation of the study is related to the fact that an equilibration time of 20 minutes for isoflurane was expected to result in adequate equilibration between the end-tidal concentration and the concentration in the vessel-rich group, which includes the site of effect, whereas use of a constant rate infusion for propofol was expected to yield a concentration of propofol in the blood and effect site that was probably still changing.[18,19] It is commonly believed that 4 or 5 terminal half-lives are necessary to reach steady-state conditions when a constant rate infusion is used, and the terminal half-life of propofol is reportedly 55 minutes in cats.[19] The initial bolus is expected to reduce this time slightly, but 20 minutes was insufficient to reach a stable effect-site concentration. Propofol was selected because its use for urodynamic measurements has been reported in dogs,[6] and the infusion time was selected to be consistent with the isoflurane group and to mimic an anesthetic regimen that could be used clinically. Infusing propofol for 4 or 5 terminal half-lives (ie, approx 4 hours) is obviously not possible in clinical situations. The effect of changing plasma and effect-site concentrations of propofol on urodynamic measurements is unclear.

Unfortunately, there were no control cats with which to compare our data. Although the primary investigator (JLW) has performed urodynamic procedures in unanesthetized cats by use of the same equipment, they were acclimated to the procedure during a period of several weeks, which would not likely be possible in a clinical setting. Furthermore, values for MUPs of unanesthetized research cats in which the investigators used hobbles, a harness, and a bag for restraint of cats have been reported.[16] Cystometrograms were not performed in that study, and investigators used microtip pressure catheters attached to a polygraph to obtain their measurements, which makes it difficult to compare results of their study with those of the study reported here. Clinically, most cats undergoing this procedure would require some form of chemical restraint. Anesthetic doses in our study were based on clinical experience and results of preliminary experiments as well as on a published study.[20] The low doses of isoflurane and propofol were selected to cause deep sedation or a light plane of anesthesia, whereas the high doses were selected to cause a light surgical plane of anesthesia.

On the basis of the cystometrogram and UPP data compiled during this study, we believe that urodynamic testing can be performed in healthy female cats. Clinically, the low-dose propofol regimen may be the easiest to titrate and maintain and yielded diagnostic-quality detrusor reflexes in all 6 cats. Although UPP data for the isoflurane protocol were not available for analysis, diagnostic tracings were obtained in cats anesthetized with propofol. These data have helped to establish appropriate anesthetic regimens for urodynamic evaluation of female cats and can serve as a template for additional studies and clinical evaluation of cats with lower urinary tract disease. Studies are needed in male cats to provide urodynamic measurements. Standardization of the methods and equipment for these diagnostic tests is essential to allow meaningful comparisons to be made in cats with lower urinary tract disorders.

a. Isoflo, Abbott Animal Health, North Chicago, Ill.
b. Rascal II, Ohmeda, Salt Lake City, Utah.
c. Medical gas analyzer LB1, Beckman Instruments, Schiller Park, Ill.
d. Isoflurane primary standard, Matheson Gas Products, Newark, Calif.
e. Propoflo, Abbott Animal Health, North Chicago, Ill.
f. Urovision Janus V system, Life-Tech Inc, Stafford, Tex.
g. DLc-6P, Life-Tech Inc, Stafford, Tex.

References

1. Lane IF, Fischer JR, Miller E, et al. Functional urethral obstruction in 3 dogs: clinical and urethral pressure profile findings. *J Vet Intern Med* 2000;14:43–49.
2. Rawlings C, Barsanti JA, Mahaffey MB, et al. Evaluation of colposuspension for treatment of incontinence in spayed female dogs. *J Am Vet Med Assoc* 2001;219:770–775.
3. Rawlings CA, Coates JR, Chernosky A, et al. Stress leak point pressures and urethral pressure profile tests in clinically normal female dogs. *Am J Vet Res* 1999;60:676–678.
4. Lane IF. Feline urodynamic procedures. *Vet Clin North Am Small Anim Pract* 1996;26:423–439.
5. Hamaide AJ, Verstegen JP, Snaps FR, et al. Validation and comparison of the use of diuresis cystometry and retrograde filling cystometry at various infusion rates in female Beagle dogs. *Am J Vet Res* 2003;64:574–579.
6. Byron JK, March PA, DiBartola SP, et al. Comparison of the effect of propofol and sevoflurane on the urethral pressure profile in healthy female dogs. *Am J Vet Res* 2003;64:1288–1292.
7. Byron JK, March PA, Chew DJ, et al. Effect of phenylpropanolamine and pseudoephedrine on the urethral pressure profile and continence scores of incontinent female dogs. *J Vet Intern Med* 2007;21:47–53.
8. Rawlings CA, Barsanti JA, Chernosky AM, et al. Results of

cystometry and urethral pressure profilometry in dogs sedated with medetomidine or xylazine. *Am J Vet Res* 2001;62:167–170.
9. Gregory CR, Willits NH. Electromyographic and urethral pressure evaluations: assessment of urethral function in female and ovariohysterectomized female cats. *Am J Vet Res* 1986;47:1472–1475.
10. Flisser AJ, Blaivas JG. Role of cystometry in evaluating patients with overactive bladder. *Urology* 2002;60(suppl 1):33–42.
11. Katofiasc MA, Nissen J, Audia JE, et al. Comparison of the effects of serotonin selective, norepinephrine selective, and dual serotonin and norepinephrine reuptake inhibitors on lower urinary tract function in cats. *Life Sci* 2002;71:1227–1236.
12. Klevmark B. Natural pressure-volume curves and conventional cystometry. *Scand J Urol Nephrol Suppl* 1999;201:1–4.
13. Abrams P. Urodynamic techniques. In: *Principles of urodynamics*. London: Springer-Verlag, 2006;64–71.
14. Ness TJ, Powell-Boone T, Cannon R, et al. Psychophysical evidence of hypersensitivity in subjects with interstitial cystitis. *J Urol* 2005;173:1983–1987.
15. Plumb DC. In: *Plumb's veterinary drug handbook*. 5th ed. Ames, Iowa: Blackwell Publishing Professional, 2005;670–671.
16. Mawby DI, Meric SM, Crichlow EC, et al. Pharmacological relaxation of the urethra in male cats: a study of the effects of phenoxybenzamine, diazepam, nifedipine and xylazine. *Can J Vet Res* 1991;55:28–32.
17. Gregory CR, Holliday TA, Vasseur PB, et al. Electromyographic and urethral pressure profilometry: assessment of urethral function before and after perineal urethrostomy in cats. *Am J Vet Res* 1984;45:2062–2065.
18. Yasuda N, Lockhart SH, Eger EI II, et al. Kinetics of desflurane, isoflurane, and halothane in humans. *Anesthesiology* 1991;74:489–498.
19. Adam HK, Glen JB, Hoyle PA. Pharmacokinetics in laboratory animals of ICI 35 868, a new i.v. anaesthetic agent. *Br J Anaesth* 1980;52:743–746.
20. Pypendop BH, Pascoe PJ, Ilkiw JE. Effects of epidural administration of morphine and buprenorphine on the minimum alveolar concentration of isoflurane in cats. *Am J Vet Res* 2006;67:1471–1475.