Published in final edited form as:

Am J Vet Res. 2011 April ; 72(4): 578–582. doi:10.2460/ajvr.72.4.578.

Urodynamic evaluation of female cats with idiopathic cystitis

Christine H. Wu, DVM, C. A. Tony Buffington, DVM, PhD, Matthew O. Fraser, PhD, and Jodi L. Westropp, DVM, PhD

Veterinary Medical Teaching Hospital (Wu) and the Department of Medicine and Epidemiology (Westropp), School of Veterinary Medicine, University of California-Davis, Davis, CA 95616; the Department of Veterinary Clinical Sciences, College of Veterinary Medicine, The Ohio State University, Columbus, OH 43210 (Buffington); and the Division of Urology and the Durham Veterans Affairs Medical Center, Institute for Medical Research, Duke University Medical Center, Durham, NC 27710 (Fraser)

Abstract

Objective—To compare values of urodynamic measurements of cats with idiopathic cystitis (IC) with previously published data for healthy female cats.

Animals—11 female cats with IC.

Procedures—2 sequential cystometrograms and 2 urethral pressure profiles were obtained for each cat. All tracings were evaluated for evidence of overactive urinary bladder (OAB). Maximum urethral pressure (MUP), maximum urethral closure pressure (MUCP), and functional profile length were recorded.

Results—Only 3 cats had obvious micturition events. None of the 11 cats had evidence of OAB. Although not significant, threshold pressure was lower in cats with IC than in healthy cats (mean $\pm$ SD, 89.0 ± 12.0 cm H₂O vs 75.7 ± 16.3 cm H₂O, respectively); however, the total volume infused was significantly lower in cats with IC (4.8 ± 2.1 mL/kg vs 8.3 ± 3.2 mL/kg). The MUCP was significantly higher in cats with IC than in healthy cats (158.0 ± 47.7 cm H₂O vs 88.9 ± 23.9 cm H₂O, respectively). The MUP was also significantly higher in all portions of the urethra in cats with IC.

Conclusions and Clinical Relevance—No evidence of OAB was identified in any cat evaluated; therefore, medications used to target this abnormality did not appear justified. The high MUCP in cats with IC suggested that α_1 -adrenoceptor antagonists or skeletal muscle relaxants may be useful in this disease, and if these data were applicable to male cats, then α_1 -adrenoceptor antagonism may help prevent recurrent obstructive IC. Further studies are indicated to determine the effects, if any, these drugs might have in cats with IC.

In cats, IC is a chronic disease that results in clinical signs related to the urinary bladder such as changes in urinary frequency, urinary urgency, and inappropriate urinations. The cause of the disease in cats is unknown, although abnormalities in the nervous^{1–3} and

Address correspondence to Dr. Westropp, jlwestropp@ucdavis.edu.

Presented as an oral presentation at the 27th Annual Forum of the American College of Veterinary Internal Medicine, Montreal, June 2009.

endocrine⁴ systems have been documented. Furthermore, studies have revealed abnormalities related to alterations in urinary bladder permeability^{5,6} that may be mediated by the sympathetic nervous system.^{3,7–9}

Humans can develop a chronic disease termed PBS-IC, the nature of which appears similar to that of IC in cats.¹⁰ Diagnostic tests for both species include urinalysis, bacterial culture of urine, and imaging to rule out cystic calculi or neoplasia as the cause for the clinical signs. In humans, urodynamic evaluations also can be performed to identify OAB, which can be a separate or concurrent abnormality in humans with PBS-IC.¹¹ Urodynamic evaluations may be useful for establishing the presence of muscle overactivity¹¹ or urinary bladder outlet obstruction in patients with lower urinary tract signs.¹² Although urodynamic procedures are not routinely performed in cats, advances in equipment and standardized protocols¹³ have made such diagnostic methodologies increasingly available. The purpose of the study reported here was to evaluate urodynamic parameters in cats with IC and compare these data with previously published data for healthy cats obtained by the same research group with the same anesthetic protocols and equipment.¹³

Materials and Methods

Animals

The study included 11 female spayed cats that had been relinquished by their owners because of variable combinations of stranguria, hematuria, pollakiuria, and inappropriate urinations. Cats were evaluated and housed at The Ohio State University Veterinary Teaching Hospital. Evaluation consisted of a complete physical examination, CBC, serum biochemical analysis, urinalysis, urine bacteriologic culture, and abdominal radiography or cystoscopy at the time of arrival at the hospital. After results of the laboratory tests were obtained, a diagnosis of IC was made on the basis of a disease-compatible history and the exclusion of other defined causes for signs for lower urinary tract signs such as urolithiasis, infection, and neoplasia.

Food was withheld from cats the night prior to the experimental procedures. All cats were monitored daily, and none had any signs related to the lower urinary tract at the time of the procedures. Urine samples for urinalysis and bacterial culture were obtained by urinary bladder catheterization immediately prior to beginning the urodynamic procedures to ensure that no cats with a positive culture result were included in the data analysis. The Animal Care and Use Committee at The Ohio State University approved all of the experimental procedures.

Anesthesia

Each cat was anesthetized with propofol^a as described elsewhere.¹³ Briefly, an IV catheter was placed into a cephalic vein and a bolus (2 mg/kg) of propofol was administered, followed by a propofol CRI at 0.2 mg/kg/min. If this degree of anesthesia did not yield adequate sedation, the CRI was increased to a maximum of 0.3 mg/kg/min until the cat was

^aPropofol, Abbott Animal Health, North Chicago, Ill.

adequately sedated and then decreased to 0.2 mg/kg/min for 15 minutes prior to initiation of the procedures. Oxygen (2 L/min) was delivered via a face mask.

If a cat was too fractious to allow IV catheter placement, additional anesthesia was administered by placing the cat in an induction chamber and administering isoflurane^b in oxygen. Once an appropriate anesthetic depth (approx 2 to 3 minutes in the chamber) was achieved, an IV catheter was placed and the propofol was administered as described for the other cats. Just enough isoflurane was provided to permit safe placement of IV catheters, and the isoflurane was discontinued afterward. Cats that received isoflurane were subsequently maintained on a propofol infusion for 15 minutes before the trial was started to allow the effects of isoflurane to dissipate.

In all cats, a Doppler ultrasonic flow detector was used to evaluate HR, which was recorded every minute. Respiratory rate was measured by counting thoracic excursions every minute. Body temperature was assessed at the beginning and at the end of the procedure by use of a rectal thermometer. Prior to beginning the urodynamic procedures, propofol infusion for a total of 15 minutes was provided to ensure adequate anesthesia. After completion of all procedures, all cats received 0.1 mg of buprenorphine/kg, PO, for analgesia.

Urodynamic evaluations

Two sequential cystometrograms and 2 urethral pressure profiles were obtained for each cat. All urodynamic procedures were performed by use of a commercially available system^c as described elsewhere.¹³ Briefly, once each cat had reached a stable plane of anesthesia, a 6F double-lumen urinary catheter^d was aseptically placed into the urinary bladder through the urethra and the bladder was emptied. The catheter was then connected to a pressure transducer for continuous measurement of intravesical pressure. Resting urinary bladder pressure was recorded. Warm sterile water was then infused at a rate of 4 mL/min, and pressures were recorded until an obvious micturition event was noted or until the intravesical pressure reached 85 cm H₂O. Threshold pressure and volume were recorded when an active presumed urinary bladder contraction was detected. When an active micturition event was not observed, the maximal urinary bladder pressure and volume were recorded. Urinary bladder compliance was calculated for cats that had an active micturition event as follows: amount of fluid infused/(bladder pressure – resting bladder pressure). Heart and respiratory rates were recorded every minute, as were the time of urinary bladder contraction, when any fluid passively leaked around the catheter, or when the intravesical pressure reached 85 cm H₂O.

After completion of cystometrography, urethral pressure profile measurements were obtained with the same 6F double-lumen catheter used for the cystometrograms. 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 urinary bladder trigone. A 3-way stopcock was applied to

^bIsoflo, Abbott Animal Health, North Chicago, Ill.

^cUrovision Janus V system, Life-Tech Inc, Stafford, Tex.

^dDLC-gP, Life-Tech Inc, Stafford, Tex.

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 and skeletal muscle portions of the urethra as described elsewhere.¹⁴ The MUCP was calculated by subtracting the resting urinary bladder pressure from the MUP value obtained in the portion of the urethra corresponding to skeletal muscle. The functional profile length 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.

Statistical analysis

A paired *t* test was used to compare the first and second replicates from the study. A Student *t* test was used to compare threshold pressure and compliance obtained in the cats with IC that had micturition reflexes with the previously published data for healthy cats obtained with the same anesthetic protocols and equipment.¹³ For the urethral pressure profile evaluations, the MUP, MUCP, and functional profile length were compared with previously published data in the same manner. Results are reported as mean $\pm$ SD; a value of $P < 0.05$ was considered significant.

Results

Animals

The mean age of the 11 cats was 6.2 years (range, 3 to 9.7 years), and mean body weight was 5.8 kg (range, 4.3 to 7.8 kg). These values did not differ significantly when compared with historical values for the healthy cats ($P = 0.60$ and $P = 0.45$, respectively). One of the 11 cats required a higher initial propofol CRI (0.3 mg/kg/min) to achieve an adequate depth of anesthesia to allow urinary catheter placement. Two additional cats required the use of isoflurane for safe IV catheter placement. No anesthetic complications were observed during the study. Gross hematuria was observed immediately after the procedures in 4 cats. In addition, stranguria and pollakiuria were observed in 3 cats immediately after anesthetic recovery, and these signs lasted for approximately 4 to 6 hours.

Cystometrography

A urinary tract infection was diagnosed in 1 cat, so data collected from it were not included in the statistical analysis. Of the remaining 10 cats, only 3 had identifiable micturition events. Passive leakage of the distending fluid around the urinary catheter was observed in 2 cats. No observable urinary bladder voiding contractions were observed in the remaining 5 cats before the procedure was stopped, when the intravesical pressure reached 85 cm H₂O. No evidence of OAB was detected on any of the tracings from these cats.

No significant (all $P > 0.10$) differences were identified between the first and second replicates for any measured variable from the 3 cats that had micturition events. No significant difference was found when evaluating threshold pressures in the 3 cats with IC that had a defined micturition event, compared with historical values for the healthy cats (89.0 ± 12.0 cm H₂O vs 75.7 ± 16.3 cm H₂O, respectively; $P = 0.17$; Table 1), whereas

threshold volume per kilogram of body weight (3.7 ± 1.3 mL/kg vs 8.3 ± 3.2 mL/kg; $P = 0.003$) and compliance (0.30 ± 0.15 mL/cm H₂O vs 0.5 ± 0.4 mL/cm H₂O; $P = 0.03$) were significantly lower in these cats with IC than in the healthy cats.

When data from all 10 IC cats were analyzed, no significant ($P = 0.06$) difference in the maximal pressure from the historical value for healthy cats was evident (92.3 ± 15.8 cm H₂O vs 75.7 ± 16.3 cm H₂O, respectively), whereas cats with IC had significantly ($P < 0.001$) lower volumes infused per kilogram of body weight (4.8 ± 2.1 vs 8.3 ± 3.2).

Cats with IC had a significantly lower percentage change in HR during the procedure than did healthy cats ($8.5 \pm 9.1\%$ vs $17.0 \pm 8.0\%$, respectively; $P = 0.01$; Table 2). No significant differences in HR, RR, or percentage change in RR were evident at the completion of the testing.

Urethral pressure profiles

Urethral pressure profiles were obtained for 9 cats without complications (Table 3). Cats with IC had significantly higher MUP in the smooth muscle portion of the urethra than did healthy cats. The MUP in the skeletal muscle portion and the MUCP were significantly higher in cats with IC than in healthy cats (165.1 ± 48.6 cm H₂O vs 106.4 ± 25.1 cm H₂O [$P = 0.001$] and 158 ± 47.7 cm H₂O vs 88.9 ± 23.9 cm H₂O [$P < 0.001$], respectively).

Although 1 cat in the IC group had unusually high urethral pressure values, compared with the other cats in that group, particularly in the skeletal muscle portion of the urethra (MUP = 242.5 cm H₂O), even with removal of this cat's data from the analysis, the difference between groups for MUP and MUCP remained significant ($P = 0.003$). No significant differences in the functional profile length were evident between the 2 groups. While obtaining the profiles, HRs in the cats with IC increased significantly ($P = 0.008$), compared with values in healthy cats ($6.6 \pm 9.0\%$ vs $-1.8 \pm 3.5\%$). Percentage change in RR did not differ between the 2 groups.

Discussion

In the present study, urodynamic procedures were successfully performed on female cats with IC when an anesthetic protocol similar to that reported for healthy cats was used.¹³ Some urologists have recommended urodynamic testing for human patients suspected of having PBS-IC, primarily to rule out other urine-voiding disorders such as OAB.^{11,15–17} Urodynamic testing also can be performed to determine whether patients with refractory OAB may have concurrent PBS-IC.^{18,19} Concurrent functional urinary bladder outlet obstruction in humans with PBS-IC is also possible.¹² To the authors' knowledge, use of such diagnostic approaches in cats with FIC has not been evaluated with standardized equipment and protocols. Although there is a report²⁰ of urethral pressure parameters in urination-obstructed male cats, cystometrograms were not performed. For this reason and because of different protocols and equipment used, data from that study cannot be compared with ours.

None of the cats with IC had evidence of OAB when evaluating their cystometrograms. This is an important finding because treatment for OAB in humans (and often in animals)

warrants the use of anticholinergic drugs,²¹ whereas these drugs are of little value in the treatment of PBS-IC.²² Therefore, given our findings, the use of anticholinergic drugs is likely to be of little benefit in cats suspected of having IC. In the 3 cats that had a defined micturition event, urinary bladder compliance (and therefore the volume infused per kilogram of body weight) was significantly lower than published values for healthy cats.¹³ These findings are similar to those reported for humans with PBS-IC¹⁷ and cats with IC,²³ but the cause of the decrease in compliance remains unclear. Most humans report that pain is associated with the need to void urine and that the urinary bladder cannot be increased to its capacity, which could lead to a decrease in compliance.¹⁹ The cats in the present study were anesthetized with a low dose of propofol, and we were unable to identify whether any of the cats had pain. Because abnormalities of the central and peripheral elements of the micturition circuit have been identified in cats with IC, the initial inciting cause of the altered compliance cannot be determined through urodynamic evaluations.

Although none of the study cats had signs of IC at the time of the study, 3 of 10 had stranguria and pollakiuria and 4 had hematuria immediately after the study was completed. These clinical signs lasted from 4 to 6 hours, requiring careful monitoring and analgesic administration. On the basis of the aforementioned signs, all cats evaluated were given analgesics immediately after the urodynamic evaluations. After the procedures, 0.01 mg/kg of buprenorphine was given to all cats. Such signs were not observed in any of the healthy cats previously evaluated, and analgesics did not appear necessary for cats in that group. Because the urinary bladders of cats with IC were infused to higher pressures than were those of healthy cats, it is possible this caused more discomfort in cats with IC immediately after the procedure. Resolution of clinical signs could have been due to analgesic administration as well as the possibility that hydrodistention of the urinary bladder provided some transient pain relief several hours afterward.²⁴

Because cats with IC reportedly have high plasma catecholamine concentrations,¹ we expected a greater increase in HR during cystometrography in cats with IC than in healthy cats. However, what we found was that healthy cats had a higher percentage increase in HR during cystometrography. The cats with IC had higher HRs at the beginning of cystometrography than did healthy cats, which may have decreased the percentage change in HR during filling of the urinary bladder.

Cats with IC had significantly higher closure pressures in the smooth and skeletal muscle portions of the urethra than had healthy cats. Urinary bladder outflow obstruction has been reported in women with PBS-IC, and in 1 study,¹² the obstruction was localized to the area of the external urethral sphincter. It was postulated that this area was in spasm in response to nearby inflammation, which should abate in diseases of short duration, but that in diseases such as PBS-IC, the condition could become permanent.²⁵ Similar recent findings in humans have also been reported,¹² and it has been hypothesized that these urodynamic and clinical findings could be due to chronic pain associated with the lower urinary tract. Cats with IC can develop signs suggestive of pain such as vocalization when urinating, excessive perineal grooming, and hiding; consequently, pain associated with the lower urinary tract might account for the increase in urethral pressures detected in our study. Finally, rats with partial urethral outflow obstruction can develop an increase in urinary bladder c-fiber upregulation,

leading to a decrease in compliance,²⁶ which was also observed in our study. Although our findings pertain to female cats, if the data can be extrapolated to male cats, they might explain, in addition to anatomic differences, the reason male cats with IC are prone to urethral obstruction. Therefore, smooth muscle relaxants such as α_1 -adrenoceptor antagonists and skeletal muscle relaxants could be considered for treating cats with IC. Additional cats will need to be evaluated to determine the effects, if any, these drugs might have on the disease.

The present study had several limitations. First, a defined micturition event was observed in only 3 of the 10 cats evaluated. The reason micturition occurred in only 3 cats could not be determined, and careful steps were taken to ensure the anesthetic and monitoring parameters used were similar to those used in the previous study¹³ involving healthy cats. Furthermore, although the healthy cats and cats with IC were evaluated at 2 universities, the same urodynamic equipment and catheters were used; the primary investigator (JLW) was present for both experimental studies. Although the cats with IC and the healthy cats received similar doses of propofol, the differences in the number of micturition events could be a result of an altered response of cats with IC to this drug. Propofol administration reportedly primarily affects the parasympathetic nervous system,²⁷ and additional studies would be required to determine whether alterations in sympathovagal tone (ie, HR variability) exist in cats with IC. It is also possible that a voiding contraction could have occurred if the intravesical pressure had been allowed to exceed 85 cm H₂O; however, we were concerned that would lead to excessive trauma to the urinary bladder and severe clinical signs when the cats recovered. Although only 3 cats had a defined micturition event, when the maximal pressures attained and maximal volume per body weight were evaluated in the cats with IC, the pressures were still higher and volume infused approximately half of that found in the healthy cats. Differences in the reproducibility of urodynamic data are always of concern. Even in humans, reproducibility can be an issue. Therefore, the International Consultation on Incontinence has suggested establishing objective data such as HR variability during urodynamic procedures.²⁸ The same needs to be considered for studies involving animals.

A second limitation was that only 2 cystometrograms and urethral pressure profiles were obtained for each cat, and these data were not obtained again later to allow assessment of repeatability of the results. Human data suggest repeated urinary bladder distention may lead to an increase in physiologic and perceptual responses to pain.²⁹ A series of cystometrograms with medium or rapid filling rates also can lead to a gradual increase in urinary bladder capacity, a phenomenon described as hysteresis.³⁰ Several cats with IC had signs of pain and hematuria after the study procedures, and further evaluation would likely have contributed to more discomfort that was observed.

Only female cats were evaluated in the present study. Although IC can occur in both sexes, commercial catheters were not available for use with our equipment to perform the same diagnostic evaluations in male cats. Finally, although none of the cats had any signs of lower urinary tract disease at the time of evaluation, their previous signs were severe enough to have had them relinquished to the teaching hospital. Therefore, the study cats may be a more severe representation of cats with IC, and the detected abnormalities may not be applicable to all cats with IC.

Because there was no evidence of OAB in any of the cats evaluated, use of medications to target this abnormality does not seem justified in cats with IC. Routine use of urodynamic testing to evaluate cats with IC for OAB may not be warranted, but evaluation of a larger group of client-owned cats may be necessary to address this supposition more thoroughly. The increase in MUCP in cats with IC suggests that α_1 -adrenoceptor antagonists or skeletal muscle relaxants may be useful for the relaxation of the urethral sphincter in such cats, and if these data can be applied to male cats, α_1 -adrenoceptor antagonism may help prevent recurrent obstructive IC.

Acknowledgments

The authors thank Judi Stella for technical assistance.

Supported in part by the Center for Companion Animal Health, University of California-Davis.

Abbreviations

CRI	Constant rate infusion
HR	Heart rate
IC	Interstitial cystitis
MUCP	Maximum urethral closure pressure
MUP	Maximum urethral pressure
OAB	Overactive urinary bladder
PBS-IC	Painful bladder syndrome–interstitial cystitis
RR	Respiratory rate

References

- Westropp JL, Kass PH, Buffington CA. Evaluation of the effects of stress in cats with idiopathic cystitis. *Am J Vet Res.* 2006; 67:731–736. [PubMed: 16579769]
- Westropp JL, Kass PH, Buffington CA. In vivo evaluation of alpha(2)-adrenoceptors in cats with idiopathic cystitis. *Am J Vet Res.* 2007; 68:203–207. [PubMed: 17269887]
- Sculptoreanu A, de Groat WC, Buffington CA, et al. Abnormal excitability in capsaicin-responsive DRG neurons from cats with feline interstitial cystitis. *Exp Neurol.* 2005; 193:437–443. [PubMed: 15869946]
- Westropp JL, Welk K, Buffington CA. Small adrenal glands in cats with feline interstitial cystitis. *J Urol.* 2003; 170:2494–2497. [PubMed: 14634458]
- Lavelle JP, Meyers SA, Ruiz WG, et al. Urothelial pathophysiological changes in feline interstitial cystitis: a human model. *Am J Physiol Renal Physiol.* 2000; 278:F540–F553. [PubMed: 10751214]
- Buffington CA, Blaisdell JL, Binns SP Jr, et al. Decreased urine glycosaminoglycan excretion in cats with interstitial cystitis. *J Urol.* 1996; 155:1801–1804. [PubMed: 8627887]
- Birder LA, Barrick SR, Roppolo JR, et al. Feline interstitial cystitis results in mechanical hypersensitivity and altered ATP release from bladder urothelium. *Am J Physiol Renal Physiol.* 2003; 285:F423–F429. [PubMed: 12759226]
- Birder LA, Nealen ML, Kiss S, et al. Beta-adrenoceptor agonists stimulate endothelial nitric oxide synthase in rat urinary bladder urothelial cells. *J Neurosci.* 2002; 22:8063–8070. [PubMed: 12223560]

9. Birder LA, Ruan HZ, Chopra B, et al. Alterations in P2X and P2Y purinergic receptor expression in urinary bladder from normal cats and cats with interstitial cystitis. *Am J Physiol Renal Physiol*. 2004; 287:F1084–F1091. [PubMed: 15251862]
10. Westropp JL, Buffington CA. In vivo models of interstitial cystitis. *J Urol*. 2002; 167:694–702. [PubMed: 11792956]
11. Dell JR, Mokrzycki ML, Jayne CJ. Differentiating interstitial cystitis from similar conditions commonly seen in gynecologic practice. *Eur J Obstet Gynecol Reprod Biol*. 2009; 144:105–109. [PubMed: 19409685]
12. Cameron AP, Gajewski JB. Bladder outlet obstruction in painful bladder syndrome/interstitial cystitis. *Neurourol Urodyn*. 2009; 28:944–948. [PubMed: 19301413]
13. Cohen TA, Westropp JL, Kass PH, et al. Evaluation of urodynamic procedures in female cats anesthetized with low and high doses of isoflurane and propofol. *Am J Vet Res*. 2009; 70:290–296. [PubMed: 19231964]
14. Gregory CR, Willits NH. Electromyographic and urethral pressure evaluations: assessment of urethral function in female and ovario-hysterectomized female cats. *Am J Vet Res*. 1986; 47:1472–1475. [PubMed: 3740618]
15. Hanno P, Dmochowski R. Status of international consensus on interstitial cystitis/bladder pain syndrome/painful bladder syndrome: 2008 snapshot. *Neurourol Urodyn*. 2009; 28:274–286. [PubMed: 19260081]
16. Forrest JB, Moldwin R. Diagnostic options for early identification and management of interstitial cystitis/painful bladder syndrome. *Int J Clin Pract*. 2008; 62:1926–1934. [PubMed: 19166439]
17. Kim SH, Kim TB, Kim SW, et al. Urodynamic findings of the painful bladder syndrome/interstitial cystitis: a comparison with idiopathic overactive bladder. *J Urol*. 2009; 181:2550–2554. [PubMed: 19375103]
18. Awad SA, MacDiarmid S, Gajewski JB, et al. Idiopathic reduced bladder storage versus interstitial cystitis. *J Urol*. 1992; 148:1409–1412. [PubMed: 1433539]
19. Macdiarmid SA, Sand PK. Diagnosis of interstitial cystitis/painful bladder syndrome in patients with overactive bladder symptoms. *Rev Urol*. 2007; 9:9–16. [PubMed: 17396167]
20. Straeter-Knowlen IM, Marks SL, Rishniw M, et al. Urethral pressure response to smooth and skeletal muscle relaxants in anesthetized, adult male cats with naturally acquired urethral obstruction. *Am J Vet Res*. 1995; 56:919–923. [PubMed: 7574161]
21. Wefer J, Truss MC, Jonas U. Tolterodine: an overview. *World J Urol*. 2001; 19:312–318. [PubMed: 11760779]
22. Minaglia S, Ozel B, Bizhang R, et al. Increased prevalence of interstitial cystitis in women with detrusor overactivity refractory to anticholinergic therapy. *Urology*. 2005; 66:702–706. [PubMed: 16230120]
23. Roppolo JR, Tai C, Booth AM, et al. Bladder Adelta afferent nerve activity in normal cats and cats with feline interstitial cystitis. *J Urol*. 2005; 173:1011–1015. [PubMed: 15711367]
24. Rovner E, Probert KJ, Brensinger C, et al. Treatments used in women with interstitial cystitis: the interstitial cystitis data base (ICDB) study experience. The Interstitial Cystitis Data Base Study Group. *Urology*. 2000; 56:940–945. [PubMed: 11113737]
25. Webster JR. Combined video/pressure/flow cystourethrography in female patients with voiding disturbances. *Urology*. 1975; 5:209–215. [PubMed: 1167714]
26. Yoshimura N, Seki S, Chancellor MB, et al. Targeting afferent hyperexcitability for therapy of the painful bladder syndrome. *Urology*. 2002; 59:61–67. [PubMed: 12007524]
27. Akamatsu T, Fukuyama H, Kawamata T. The effects of visual, auditory, and mixed cues on choice reaction in Parkinson's disease. *J Neurol Sci*. 2008; 269:118–125. [PubMed: 18279895]
28. Mehnert U, Knapp PA, Mueller N, et al. Heart rate variability: an objective measure of autonomic activity and bladder sensations during urodynamics. *Neurourol Urodyn*. 2009; 28:313–319. [PubMed: 19058189]
29. Ness TJ, Powell-Boone T, Cannon R, et al. Psychophysical evidence of hypersensitivity in subjects with interstitial cystitis. *J Urol*. 2005; 173:1983–1987. [PubMed: 15879797]
30. Abrams, P. *Urodynamics*. London: Springer-Verlag; 2006. Principles of urodynamics; p. 64-71.

Table 1

Mean $\pm$ SD values for threshold pressure and volume infused per unit of body weight obtained during cystometrography for female cats with IC with a defined micturition ($n = 3$) event as compared with healthy female cats (6).

Variable	IC	Healthy	<i>P</i> value
Threshold pressure (cm H ₂ O)	89.0 $\pm$ 12.0	75.7 $\pm$ 16.3*	0.17
Total volume (mL/kg)	3.7 $\pm$ 1.3	8.3 $\pm$ 3.2*	0.003
Compliance (mL/cm H ₂ O)	0.30 $\pm$ 0.15	0.5 $\pm$ 0.4*	0.03

* Data for healthy cats were obtained during a previous study¹³ involving the same anesthetic protocol and equipment.

Values of $P < 0.05$ were considered significant.

Table 2

Mean $\pm$ SD HR and RR before and after performance of cystometrography in cats with IC (n = 10) and healthy cats (6).*

Variable	IC	Healthy	P value
Initial HR (beats/min)	169 $\pm$ 27	153 $\pm$ 24	0.09
Final HR (beats/min) [†]	186 $\pm$ 27	185 $\pm$ 26	0.91
Percentage increase in HR	8.5 $\pm$ 9.1	17.0 $\pm$ 8.0	0.01
Initial RR (breaths/min)	25 $\pm$ 8.0	24 $\pm$ 6.0	0.55
Final RR [†] (breaths/min)	32 $\pm$ 11	26 $\pm$ 6.0	0.07
Percentage increase in RR	15.9 $\pm$ 24.8	4.2 $\pm$ 19.1	0.21

[†] Value determined at the time of a micturition event, urine leakage, or intravesical pressure exceeding 85 cm H₂O.

See Table 1 for remainder of key.

Table 3

Mean $\pm$ SD values for MUP, MUCP, and functional profile length for urethral pressure profile determinations in cats with IC (n = 9) and healthy cats (5).

Variable	IC	Healthy	P value
MUP (cm H ₂ O)			
Smooth muscle	71.1 $\pm$ 30.6	39.5 $\pm$ 7.2	0.003
Skeletal muscle	165.1 $\pm$ 48.6	106.4 $\pm$ 25.1	0.001
MUCP (skeletal; cm H ₂ O)	158.0 $\pm$ 47.7	88.9 $\pm$ 23.9	< 0.001
Functional profile length (cm)	5.6 $\pm$ 0.9	5.6 $\pm$ 0.4	0.92

See Table 1 for key.