

Standard Article

J Vet Intern Med 2017;31:486–491**Quantification of Urine Elimination Behaviors in Cats with a Video Recording System**

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Background: Urinary disorders in cats often require subjective caregiver quantification of clinical signs to establish a diagnosis and monitor therapeutic outcomes.

Objective: To investigate use of a video recording system (VRS) to better assess and quantify urination behaviors in cats.

Animals: Eleven healthy cats and 8 cats with disorders potentially associated with abnormal urination patterns.

Methods: Prospective study design. Litter box urination behaviors were quantified with a VRS for 14 days and compared to daily caregiver observations. Video recordings were analyzed by a behavior analysis software program.

Results: The mean number of urinations per day detected by VRS (2.5 ± 0.7) was significantly higher compared with caregiver observations (0.6 ± 0.6 ; $P < .0001$). Five cats were never observed in the litter box by their caregivers. The mean number of urinations per day detected by VRS was significantly higher for abnormal cats (2.9 ± 0.7) compared with healthy cats (2.1 ± 0.7 ; $P = .02$); there were no apparent differences in frequency between these groups reported by caregivers (0.7 ± 1.0 and 0.5 ± 1.0 , respectively). There were no differences in mean urination time between healthy and abnormal cats as determined by VRS or caregivers. Mean cover-up time determined by VRS was significantly longer in healthy cats (22.7 ± 12.9 seconds/urination) compared with abnormal cats (8.7 ± 12.9 seconds/urination; $P = .03$); differences in cover-up time were not detected by caregivers.

Conclusions and Clinical Importance: Caregivers commonly underestimate urination frequency in cats when compared to video-based observations. Video recording appears to facilitate objective assessment of urination behaviors and could be of value in future clinical studies of urinary disorders in cats.

Key words: Chronic kidney disease; Feline idiopathic cystitis; Urination frequency; Urination time.

Disorders resulting in altered urination patterns (e.g. polyuria, pollakiuria, dysuria, and periuria) are encountered frequently in feline practice. Historically, practitioners have relied upon subjective caregiver observation, interpretation, and quantification of clinical signs to establish a diagnosis and monitor therapeutic outcomes. This is especially true for lower urinary tract disorders of cats such as idiopathic cystitis for which other reliable biomarkers of disease have not been identified.^{1–3} However, the ability of caregivers to

Abbreviations:

FIC	idiopathic cystitis
IRIS	International Renal Interest Society
MH	Marie Hopfensperger (reviewer #2)
NAS	network-attached storage
RD	Ryan Dulaney (reviewer #1)
VRS	video recording system

reliably quantify urination patterns in cats can be compromised by (1) limited direct observation; (2) multiple litter boxes, cats, or caregivers within the home; (3) placement of litter boxes in secluded areas; (4) use of covered litter boxes; (5) secretive or nocturnal voiding habits of some cats; (6) ability of caregivers to recall clinical signs and interpret elimination behaviors; and (7) the caregiver placebo effect. As of yet, there have been no reported studies investigating the reliability of caregiver-based observations of abnormal urination behaviors of cats.

Use of video recording systems (VRS) and subsequent analysis of video images eliminates problems associated with primary observer inconsistency, subjectivity, and bias and provides a permanent comprehensive record of events that can be repeatedly analyzed by multiple secondary video reviewers.^{4–7} In a study of autistic behaviors of children in a classroom setting, use of a VRS resulted in a significant (44%) reduction in errors in quantifying behavior incidents compared with direct observation by classroom personnel.⁶ Likewise, when a VRS was compared to direct human observations to identify estrous behavior in dairy cows, the VRS was associated with a substantially higher rate of correct detection of ovulatory periods.⁴ Similar studies comparing caregiver observations to VRS observations

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of urination behavior patterns have not been reported in cats.

The objective of our study was to investigate the use of a VRS to identify and quantify urination behaviors in cats. The ability to record and accurately quantify urination patterns in cats with various urinary disorders could substantially enhance our ability to meaningfully assess the impact of various treatments and other risk factors on disease expression.

Materials and Methods

Study Population

The study population consisted of clinically healthy cats with owner-perceived normal urination patterns and abnormal cats with disorders potentially associated with altered urination patterns. Caregiver observation of altered urination patterns in abnormal cats was not a prerequisite for enrollment. All cats were evaluated at the Michigan State University Veterinary Medical Center (MSU VMC). For inclusion in the study, cats were between 1 and 15 years of age, housed indoors exclusively during the study, had no more than 4 litter boxes or well-defined house-soiling areas, had physical features that allowed them to be easily identified on video recordings, and had uncovered litter boxes located in an area that allowed a clear field of view for recording without compromising owner privacy. Cats were excluded if there was a change in their health status during study that prompted removal from the home, caregiver, or pet disturbing or altering position of the VRS, disabling the VRS for prolonged periods of time (>1 hour per 24 hours), with the VRS for purposes not related to the study, damaging the VRS, and caregiver unwillingness to maintain a diary of his or her cat's urination behaviors. All cats were evaluated by means of a standardized medical history and living environment questionnaire, a complete physical examination, and routine health screen consisting of a serum biochemistry profile, hematocrit and total plasma solids, a complete urinalysis, and urine culture for aerobic bacteria. Healthy cats had no history of any disease process that would alter urination behavior and were otherwise healthy on the basis of physical examination and results of the routine health screen. Abnormal cats had a current stable disease process that was likely to be associated with abnormal urination behaviors (e.g. FIC, chronic kidney disease). The study was conducted with approval of the Michigan State University Institutional Animal Care and Use Committee and the Biomedical Institutional Review Board.

Video Recording System

Once enrolled, a research team member traveled to the participant's home to set up the VRS and reviewed the study protocol with the caregiver. The VRS consisted of up to 4 internet protocol (IP) video cameras (high-definition color, motion-activated, and infrared-enabled)^a, a wireless router^b, and a network-attached storage (NAS) system.^c The IP cameras were positioned to record activity in all litter boxes and any area that was consistently used for house-soiling. Efforts were made to ensure owner privacy, and owners had the option of turning the cameras off for short periods of time (maximum of 1 hour per day). The IP cameras utilized a continuous video buffer, but would only store video once motion was detected. At that point, they would retrieve the previous 6 seconds of buffered video to document that activity. The NAS system served as an automated data recording station that securely recorded and stored video from the IP cameras. The NAS system was placed in a convenient and secure location in the home,

separate from the camera positions. The NAS contained 2 internal hard drives^d configured in a redundant array of independent disks (RAID-1) for data redundancy in case of hardware failure. Each device was preconfigured with network information that allowed for rapid installation in the participant's home in <1 hour. Once proper VRS installation was confirmed, the participating cat and all surveillance stations were photographed for identification purposes. At the end of each study, all VRS components were retrieved from the home, and video data were transferred from the NAS system to off-site storage in a secure cloud-based data archiving system.^e

Outcomes

Urination behaviors were video-recorded and quantified for 14 days and compared with caregiver observations over the same time period. Owners quantified urination behaviors on a daily basis with a standardized daily log sheet. Urination variables included (1) frequency of urination (number of urinations per day), (2) litter digging time (duration of digging with a forelimb to rake litter away to form a shallow hole before voiding), (3) urination time (duration of urination from initiation of posturing to end of posturing), (4) cover-up time (duration of raking litter over waste after voiding), (5) frequency of vocalization during urination, (6) frequency of straining (posturing with no urine production) during urination, and (7) frequency of visible blood during urination. Classification and quantification of the same urination behaviors in video recordings were performed by 2 of the authors (RD, MH), blinded to health status of the cat, by standardized operational definitions of terms and specific interpretations of behaviors. A behavior analysis software program^f was used to enumerate the frequency and calculate the elapsed time of behaviors identified by the secondary observers.

Data Reduction and Statistical Analyses

Descriptive statistics were generated for each of the population variables for both healthy and abnormal cats. The chi-square test, Mann-Whitney rank-sum test, and unpaired *t*-test were used for univariate analyses of population characteristics for significant differences between groups. Normality distribution of continuous quantitative variables was evaluated with the Shapiro-Wilk test. Continuous quantitative variables that failed normality testing were evaluated with nonparametric analyses. Data are presented as mean \pm SD.

Caregiver observations of outcome variables were collected as binary (yes/no), ordinal, or discrete numerical data. The video reviewer's observations were collected as continuous data and subsequently stratified into the identical binary or ordinal categories. The response variables of urination frequency, urination time, and cover-up time were evaluated by means of a split plot analysis of variance (ANOVA) with 1 grouping factor (healthy/abnormal), 1 repeat factor (time), and the random factors of cat (nested within group) and observer (2). Differences between groups at each time were determined by means of *t*-test, and differences between times within group by means of *t*-test with Bonferroni correction for multiple comparisons. A *P* value <.05 was considered significant. Statistical analyses were performed by a statistical software program.^g

The degree of inter-rater agreement between the video reviewers was analyzed with the Kappa statistic and weighted Kappa statistic for binary and ordinal categorical data, respectively.^h Observer agreement was considered substantial when the κ value was >0.60.^h Agreement between the video reviewers for continuous variables was analyzed by correlation using the Spearman correlation coefficient.

Results

Thirteen healthy cats and 9 abnormal cats were enrolled in the study. Three cats (2 healthy and 1 abnormal) were excluded because of camera motion activation malfunction. The remaining 11 healthy cats (7 male neutered and 4 female spayed cats) and 8 abnormal cats (3 male neutered and 5 female spayed) were included in analyses (Table 1). The abnormal group included 3 cats with chronic FIC, 1 with untreated subclinical bacteriuria, and 4 with chronic kidney disease (CKD; IRIS Stage II—3 cats, IRIS Stage III—1 cat). Seven of 8 abnormal cats had a history of caregiver-observed urinary system clinical signs including increased urination frequency, periuria, vocalization during urination, and hematuria (Table 1). Univariate analyses did not identify significant differences between healthy and abnormal groups with respect to sex, body weight, number of caregivers, multicat households, cohabitation with dogs, number of litter boxes per cat in the home, frequency of litter box hygiene, and formulation of food (exclusively dry or wet, or mixed; Table 1). However, the mean age of healthy cats was significantly less than that of abnormal cats (5.3 ± 4.1 and 10.3 ± 4.7 years, respectively; $P = .02$; Table 1). Ages of the 4 abnormal cats with CKD ranged from 12 to 15 years of age; ages of the 4 non-CKD cats ranged from 1.5 to 9.0 years of age.

Results of serum biochemistry and hematologic evaluations did not identify any clinically significant

Table 1. Population characteristics of 8 abnormal cats with disorders likely to be associated altered urination patterns and 11 clinically healthy cats before enrollment in a study quantifying urination behaviors with a video recording system.

Characteristic	Healthy (n = 11)	Abnormal (n = 8)
Sex	7 MN, 4 FS	3 MN, 5 FS
Age (years)	5.3 ± 4.1	$10.3 \pm 4.7^*$
Body Weight (kg)	5.3 ± 1.2	5.3 ± 1.5
Single caregiver home	10 (91%)	7 (88%)
Multiple cat home	7 (64%)	3 (36%)
Exclusively dry food diet	4 (36%)	2 (25%)
Caregiver-reported urinary clinical signs	0 (0%)	7 (88%) [†]
		Increased frequency 5 (63%)*
		Periuria 5 (63%)*
		Hematuria 2 (25%)
		Vocalization 1 (13%)
		Stranguria 1 (13%)
		Asymptomatic 1 (13%)
Serum Creatinine (mg/dL)	1.5 ± 0.3	1.9 ± 0.8
Urine Specific Gravity	1.062 ± 0.01	$1.035 \pm 0.02^*$
Urine pH	6.7 ± 0.6	6.6 ± 0.7
Pyuria (>5 WBCs/hpf)	0 (0%)	0 (0%)
Hematuria (>5 RBCs/hpf)	2 (18%)	2 (25%)
Crystalluria	3 (27%)	2 (25%)

FS, female spayed; MN, neutered male.

*Significantly different from healthy cats, $P < .03$.

differences between groups: All values were within normal reference intervals. The mean specific gravity of urine samples obtained from healthy cats (1.062 ± 0.01) was significantly higher compared with that of abnormal cats (1.035 ± 0.02 ; $P = .006$; Table 1). Urine specific gravities of the 4 abnormal cats with CKD ranged from 1.012 to 1.017; urine specific gravities of the 4 non-CKD cats ranged from 1.043 to 1.062. There were no significant differences between the 2 groups in regard to the prevalence of hematuria, pyuria, or crystalluria (Table 1). Quantitative cultures of urine specimens from healthy cats were negative for bacterial growth. *Staphylococcus felis* (1.5×10^4 cfu/mL) was isolated from the urine of 1 abnormal cat with subclinical bacteriuria. In this cat, urinalysis identified only bacteriuria; neither pyuria nor hematuria was observed on sediment examination. Although subclinical bacteria is defined as clinically relevant bacteriuria in the absence of clinical and cytologic evidence of urinary tract infection (UTI),⁹ subsequent video analyses of this cat identified increased frequency of urination. Therefore, this cat was included in the abnormal group for statistical analyses.

Overall, a total of 632 urinations were detected by VRS or reported by caregivers; 623 urination events took place in the litter box; 9 events took place outside of the litter box. The VRS detected 623 of 632 events (99%), all of which were detected in the litter box. Caregivers detected only 169 of 632 (27%) events, 160 of which were observed in the litter box and 9 outside the litter box. Five cats were never observed in the litter box by their caregivers. The overall mean number of urinations per day detected by the VRS (2.5 ± 0.7 , range: 0–5) was significantly higher compared with caregiver observations (0.6 ± 0.6 , range, 0–6; $P < .0001$). The mean number of urinations per day detected by the VRS was significantly higher for abnormal cats (2.9 ± 0.7 ; range, 1–5) compared with healthy cats (2.1 ± 0.7 ; range, 0–5; $P = .02$). There were no apparent differences in frequency between healthy and abnormal cats reported by caregivers (0.7 ± 1.0 and 0.5 ± 1.0 , respectively). Due to concerns for caregiver hypervigilance at the outset of the study, differences between caregiver and VRS observations (frequency) over time (each day of the study) were evaluated; there were no significant differences in the mean daily frequency over time for either caregiver or VRS observations.

Variation in individual cat day-to-day frequency of urination was detected by both observation methods. Caregivers reported that the number of urinations/day varied by >1 events in 5 of 11 healthy cats and 5 of 8 abnormal cats over the course of the study. The VRS identified that the number of urinations per day varied by >1 events in 9 of 11 healthy cats and 7 of 8 abnormal cats. Using the combined observations of the VRS and caregiver-reported episodes of periuria, the number of urinations/day in healthy cats over the observation period varied from 0 to 5, with 2 of 11 cats having a range (maximum–minimum) of >2 urinations/day (Fig 1). The number of urinations/day in abnormal cats

over the observation period varied from 0 to 5, with 4 of 8 cats having a range of >2 urinations/day (Fig 1). Interestingly, 2 normal and 3 abnormal cats were observed not to have urinated in at least one 24-hour period (Fig 1).

The mean urination times for healthy and abnormal cats determined by VRS were 12.7 ± 4.9 and $11.4.0 \pm 4.2$ seconds/urination, respectively. The urination time for both healthy and abnormal cats estimated by caregivers was reported as <5 seconds. There were no differences in mean urination time between healthy and abnormal cats determined by VRS or caregivers.

The mean cover-up time determined by the VRS was significantly longer in healthy cats (22.7 ± 12.9 seconds/urination) compared with abnormal cats (8.7 ± 12.9 seconds/urination; $P = .03$). The cover-up time for both healthy and abnormal cats estimated by caregivers was <30 seconds. There was no significant difference in cover-up time between healthy and abnormal cats determined by caregiver observations.

Episodes of periuria were not observed in normal cats by either caregivers or the VRS. Nine episodes of periuria were observed by caregivers in 2 of 8 abnormal cats, both of which were FIC cats. Litter digging behavior (raking to form a depression in the litter) was only observed in association with defecation events. Urination-associated vocalization was not observed in normal cats; 10 vocalization events were reported by caregivers in 3 of 8 abnormal cats (2 FIC and 1 CKD cat). Neither the VRS nor caregivers detected episodes of stranguria or macroscopic hematuria.

The weighted Kappa statistic test for assessment of inter-rater agreement between video reviewers (RD and MH) for frequency of urination was 0.9. Values >0.8 are considered to be indicative of almost perfect agreement.⁸ Spearman correlation coefficient values for urination time and cover-up time were 0.86 and 0.87, respectively, indicating a strong significant positive correlation between the 2 video reviewer's observations ($P < .001$). Due to lack of observations, we were unable

to evaluate a kappa statistic or correlation of the other variables (i.e, digging time, vocalization, straining, and hematuria).

Discussion

To our knowledge, ours was the first study comparing a VRS to caregiver observations for quantification of urine elimination behaviors in cats. The VRS detected a significantly higher number of urinations than did caregivers, with the VRS detecting 99% of all urinations compared with only 27% detected by caregivers. However, episodes of periuria and vocalization during urination were detected only by caregivers. Episodes of stranguria or hematuria were not detected by either observation method. When compared to caregivers alone, the VRS appeared to facilitate objective assessment of many, but not all, urination behaviors of cats in their home environments and could be of value in future clinical studies of urinary disorders of cats.

The 2 groups of cats in the study population included healthy cats with normal urination behavior and abnormal cats with disorders likely to be associated with altered urination patterns. Abnormal cats were included to increase the frequency and diversity of urination behaviors and allow a more comprehensive comparison of caregiver observations to those collected by the VRS. Included in this group were 4 cats with CKD, 3 cats with chronic FIC, and 1 untreated cat with presumed subclinical bacteriuria, based on the presence of clinically relevant bacteriuria in the absence of pyuria and caregiver-reported clinical signs.⁹ Interestingly, this latter cat's litter box was located in an isolated closet with limited opportunity for caregiver observation. Analysis of video recordings of this cat identified an increased frequency of urination (mean, 3.4 urinations/day) compared with healthy cats in our study (mean, 2.1 urinations/day). By definition, the diagnosis of subclinical bacteriuria depends on the veterinarian's or caregiver's perception of the absence of clinical signs of urinary tract disease.⁹ However, our observations in this case raise concerns that absence of clinical signs as perceived by caregivers could be an unreliable criterion for defining subclinical bacteriuria in cats and emphasize the need for further studies to identify and evaluate more objective indicators of host responses.

A change in urination frequency is an important and readily quantifiable diagnostic marker of urinary tract diseases in cats and is often 1 of the principal variables used to detect and localize urinary tract disorders and to monitor disease progression and response to therapeutic interventions.¹⁻³ In our study, there was considerable disparity between caregiver and VRS observations of urination frequency, with caregivers commonly underestimating the number of urinations. The overall mean number of urinations per day detected by the VRS (2.5 urinations/day) was 4-fold higher than that detected by caregivers (0.6 urinations/day). Although the VRS detected 99% of all urination events, neither observation method detected all urination events in all cats. All of the IP cameras in the

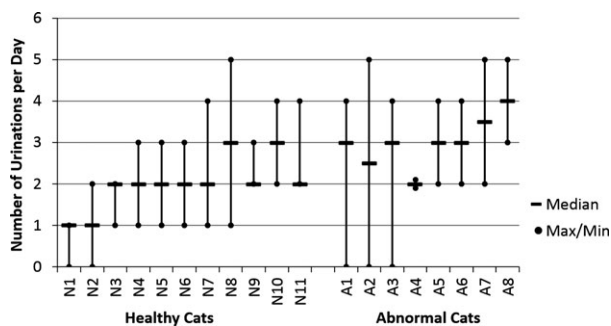


Fig 1. Distribution of the number of urinations/day (maximum, median, minimum) detected by a video recording system or by caregivers in 19 cats observed over a 14-day period. Eleven cats were clinically healthy (cats N1 to N11) and 8 cats were abnormal with urinary disorders likely to be associated with altered urination behaviors (cats A1 to A8). Closed solid circles at the top and bottom of each vertical line denote the maximum and minimum number of urinations/day, respectively. Solid horizontal bars denote the median number of urinations/day.

study were positioned over litter boxes; thus, episodes of periuria were not detected by the VRS. Caregivers, however, observed 9 episodes of periuria that involved 2 of 8 abnormal cats. Although this number represents only a small proportion (1%) of all urination events detected in the study, periuria is a common clinical sign associated with lower urinary tract diseases in cats and the limited ability of the VRS to detect periuria represents a potential limitation of the system.¹⁻³ Nevertheless, our observations suggest that the VRS provides a more objective and comprehensive record of urination frequency of cats in their home environments than can be achieved by direct caregiver observation alone.

The VRS detected a significant difference in urination frequency between healthy and abnormal cats, whereas a difference between groups was not detected based on caregiver observations. In addition, the VRS detected considerable day-to-day variation in the number of urinations in both healthy and abnormal cats. Frequency of urination is dictated by urine volume and bladder capacity and can be influenced by physiologic and pathologic processes, environmental conditions, psychosocial factors, pharmaceutical agents, and diet and fluid intake. Few studies have accurately documented the frequency of urination of healthy cats under controlled conditions^{10,11} and studies specifically documenting urination frequency in cats in home environments have not been reported. Furthermore, we are unaware of any study that has accurately documented urination frequencies in cats with various urinary tract diseases or that has established a quantitative definition of pollakiuria in cats. In 1 laboratory study,¹¹ healthy adult male cats housed individually in metabolic cages and periodically or continuously fed a dry food urinated 2.69 (± 1.93) and 2.66 (± 1.28) times per day, respectively, based on detection of urination by an electronic sensor. In another study,¹⁰ healthy adult cats housed individually in metabolic cages and fed different foods on a continuous or meal-fed basis urinated 2.4 to 3.0 times per cat per day based on detection of a temperature change in the urine collection apparatus. The mean number of urinations in healthy cats in our study was 2.1 (± 0.7) and was comparatively lower than that of laboratory-housed cats despite that fact that only 4 of 11 healthy cats in our study were fed exclusively dry food. This somewhat lower rate of urination observed in our study may reflect differences between laboratory- and home-housed cats in environmental conditions (e.g., temperature, relative humidity), husbandry practices, psychosocial factors, food composition and consistency, and water consumption.

Previous studies of elimination behavior in cats suggest that other variables (e.g., pre-elimination digging time) can be altered in cats with urine and fecal elimination problems.⁷ In our study, additional urine elimination behaviors evaluated included duration of prevoiding digging, duration of urination, duration of postvoiding covering, frequency of vocalization during urination, frequency of straining during urination, and frequency of visible blood during urination. We were unable to evaluate differences in pre-urination digging

behavior because digging was observed only before defecation in our study population. Mean urination times for healthy and abnormal cats were similar (12.7 and 11.4 seconds, respectively). Although urination time was readily quantified by the VRS, its utility as a clinical response variable requires further investigations.

Interestingly, the mean posturination cover-up time determined by the VRS was significantly longer in healthy cats compared with abnormal cats (23 vs. 9 seconds/urination, respectively). Our observations are in contrast to those of a previous study in which cover-up times were not significantly different between cats with and without elimination problems.⁷ The reasons for the difference in cover-up times between healthy and abnormal cats in our study are unknown, but most likely reflect the nature of disorders affecting the abnormal group cats. Cats with FIC or UTI may have experienced painful urination at some point, which could have conditioned these cats to associate litter box use with pain.⁷ This type of acquired litter box aversion could influence cover-up time in affected cats. Similarly, inclusion of older CKD cats in our abnormal group also could have influenced cover-up time. In general, older cats are more likely to have osteoarthritis, which may alter mobility, activity level, grooming habits, and temperament.¹² It has been documented previously that 68.8% of cats with CKD also have degenerative joint disease as a comorbidity.¹³ Although none of the cats had clinical signs of lameness, joint pain, or joint effusion on physical examination, the presence of subclinical orthopedic disease may have decreased the time that affected cats spent in cover-up activity. Regardless, variables responsible for shorter cover-up time and its clinical utility as a marker of urinary tract disease or litter box aversion require further investigations.

An increase in urination-associated vocalization often is interpreted as an indicator of painful urination (i.e., dysuria) and is considered a clinical sign of lower urinary tract disease.^{1,3} Urination-associated vocalizations were detected by caregivers in 1 CKD cat and 2 FIC cats, but vocalizations were not detected by the VRS. This difference in observations was most likely related to the lack of audio recording and variability in the position of the cat's face relative to the camera. Detection of vocalizations in the litter box could be substantially improved by incorporating audio recording into the VRS.

Stranguria and gross hematuria are also common clinical signs of urinary tract diseases in cats.¹⁻³ However, neither stranguria nor macroscopic hematuria was detected by the VRS or caregivers. It is unknown whether lack of detection of these signs was due to their absence or if it represented detection failure of both observation methods. Additional studies incorporating larger numbers of abnormal cats with disorders associated with these clinical signs would be necessary to evaluate the comparative ability of caregivers and the VRS to detect and quantify these clinical signs.

Our study had several limitations. One is that there is, as of yet, no gold standard method of quantifying urinary tract clinical signs in cats housed in their home environment. Although the VRS used in this study was

superior to caregivers for quantifying frequency of urination, urination time, and cover-up time, it was less useful for detection and quantification of periuria and dysuria. Performance of the VRS at the litter box site could be improved by incorporating audio recording and multiple cameras at each litter box into the system. However, detection of episodes of periuria that are not in close proximity to the litter box would require video surveillance of the entire household. Although feasible, implementation of such a strategy would be technically challenging and would compromise caregiver privacy. Another limitation is the number of cats and diversity of disorders represented in the abnormal group. Increasing the sample size of cats with various urinary tract disorders would allow for determination of urinary frequency, urination time, and cover-up time for specific disorders, as well as identify other urination behavior variables that may have potential value for diagnosis and monitoring of urinary disorders in cats.

In conclusion, the VRS provided a more comprehensive record of the number of urination events, as well as the duration of urinations and postvoiding cover-up behaviors, as compared to caregiver observation. However, the VRS was more limited in its ability to detect episodes of periuria and dysuria. Optimal detection and quantification of urinary signs in cats may entail a combination of observation methods. The VRS appears to facilitate more objective assessment of urination behavior in home environments than caregiver observation and could be of value in future clinical studies of urinary disorders in cats.

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Conflict of Interest Declaration: Authors declare no conflict of interest.

Off-label Antimicrobial Declaration: Authors declare no off-label use of antimicrobials.

Footnotes

^a Cloud camera DCS-2332L, D-Link US, Fountain Valley CA

^b DIR-655Xtreme N Wireless Gigabit Router, D-Link US, Fountain Valley CA

^c Diskstation DS214, Synology America Corp, Bellevue WA

^d WD Red 3 TB hard drives; Western Digital, Irvine CA

^e Microsoft SkyDrive®

^f JWatcher™

^g Statistical Analysis Software, version 9.1.3, SAS Institute, Cary, NC

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