# Effectiveness of manual bladder expression in paraplegic dogs

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**OBJECTIVE**
To determine the effectiveness of manual bladder expression in paraplegic dogs by comparing urine volumes measured by use of intermittent catheterization and ultrasonography.

**ANIMALS**
36 paraplegic dogs.

**PROCEDURES**
93 measurements of bladder volume were collected for the 36 dogs. Residual urine volume was determined by use of intermittent urethral catheterization and estimated by use of ultrasonography.

**RESULTS**
Manual bladder expression voided a mean of 49% of urine from the bladder in this population of dogs. There was no correlation ($R^2$, 0.06) between the effectiveness of manual bladder expression and body weight. Ultrasonographic estimation of bladder volume had good correlation ($R^2$, 0.62) with bladder volume determined by use of intermittent bladder catheterization, but clinically unacceptable variation for predicting actual bladder volume (mean difference, 22 mL; 95% confidence interval, –96 to 139 mL).

**CONCLUSIONS AND CLINICAL RELEVANCE**
Manual bladder expression was ineffective at completely emptying urine from the bladder of paraplegic dogs, but the effectiveness of the procedure was not affected by body weight. Manual bladder expression would likely be a useful procedure to prevent increases in pressure within the bladder. Ultrasonographic estimation of bladder volume could be a useful predictor of actual bladder volume, but it was susceptible to wide variations among dogs, and results should therefore be interpreted with caution. (*Am J Vet Res* 2017;78:107–112)

Micturition requires a synergistic action between the detrusor muscle of the bladder and the external and internal urethral sphincter muscles.[1–4] Their coordinated action requires control of segmental spinal reflexes combined with input from supraspinal centers via the spinal cord. Spinal cord injury in the thoracolumbar region leads to detrusor areflexia and increased urethral sphincter tone (ie, an upper motor neuron bladder) and eventually bladder dyssynergia.[5] The lack of afferent information on bladder pressure to the brain initially leads to prolonged urine retention, and preservation of sacral spinal reflexes caudal to the lesion in turn causes persistence of urethral tone. As bladder pressure increases with increasing urine volume, there is often overflow incontinence and vesicoureteral reflux to the kidneys. Prolonged increases in bladder pressure can lead to damage of the detrusor neuromuscular tight junctions and detrusor atony, which can be irreversible.

In the acute phase of injury, there is low urethral tone, and reflex incontinence is common.[6] By 2 weeks after spinal cord injury, involuntary detrusor contractions begin during the filling phase, which causes reflex incontinence.[7,8] However, these involuntary detrusor contractions, without supraspinal control, are not enough to completely empty the bladder. In addition, detrusor-sphincter dyssynergia develops with simultaneous contraction of the urethral sphincter when the bladder contracts. Short-lived detrusor contraction combined with increased urethral tone leads to incomplete voiding of urine from the bladder.[5]

The methods for managing bladder dysfunction in patients with spinal cord injury (manual expression, an indwelling catheter, or intermittent catheterization) are intended to frequently remove urine from the bladder to prevent prolonged urine retention.[9] Ideally, these techniques should leave the same residual urine volume as in clinically normal dogs (0.2 to 0.4 mL/kg).[10] An indwelling catheter allows efficient urine evacuation with minimal intervention once the catheter is placed. Unfortunately, placement of a urinary catheter can result in damage to the bladder or urethra, and the risk of urinary tract infection increases daily with use of an indwelling catheter, both of which can discourage use of indwelling catheters.[11–13]

**ABBREVIATIONS**
CI Confidence interval

Intermittent catheterization can be time consuming, particularly in female dogs. Manual bladder expression is thought to be quick and easy to perform in small-breed dogs, but it can be difficult in large, obese, or aggressive dogs. Because no apparatus is passed up the urethra during manual expression, the theoretical risk of urinary tract infection may be less than that for catheter-based methods, but this has not yet been determined. Nevertheless, 21% to 38% of dogs with spinal cord injury managed with manual bladder expression develop a urinary tract infection.[9,14,15] It is possible that leaving a larger residual urine volume in the bladder may increase the risk of urinary tract infection (by increasing the bladder's exposure to uropathogens that typically are rapidly and efficiently cleared from the bladder) and the risk of detrusor atony. Despite widespread clinical use of manual bladder expression, the effectiveness of this method for emptying the bladder is not known. Accurate data on the effectiveness of current bladder management techniques would allow clinicians and researchers to make objective comparisons with effectiveness of new treatments or techniques.

The criterion-referenced standard for accurate measurement of the residual urine volume requires intermittent catheterization.[16] Ultrasonographic estimation of the residual urine volume is standard practice at human hospital wards to determine whether bladder management is required, which avoids the invasive and time-consuming procedure of intermittent catheterization.[17] Intermittent catheterization has been used in our veterinary clinic by appropriately trained veterinarians and veterinary nurses. The bladder diameter has been used as an approximation of bladder volume to determine whether an intervention (eg, intermittent catheterization, indwelling catheter, or manual bladder expression) is required. Bladder volume in dogs can be accurately estimated with a few simple ultrasonographic measurements by use of a specific equation.[18–20]

The primary objective of the study reported here was to determine the effectiveness of manual bladder expression for emptying the bladder in paraplegic dogs with an upper motor neuron bladder by measuring residual urine volume after manual bladder expression. Additionally, we examined whether body weight was correlated with the residual urine volume to investigate the commonly held belief that manual bladder expression is less effective in larger dogs. Finally, we compared ultrasonographic bladder volume estimates obtained from conscious paraplegic dogs in a clinically applicable setting to determine whether estimates of bladder volumes correlated and agreed with actual bladder volumes.

## Materials and Methods

### Animals

The study population consisted of prospectively recruited client-owned dogs with naturally occurring spinal cord injury examined at the veterinary neurology referral service of the University of Bristol between October 2013 and March 2014. Details of the study were explained to owners during the initial consultation. Informed consent was obtained from owners before dogs were included in the study. The study design was approved by the local ethical committee and assigned a veterinary investigation number (VIN/13/037).

Inclusion criteria for the study were acute (within 7 days) paraplegia (with or without pelvic limb pain sensation) secondary to a spinal cord injury between the third thoracic and third lumbar spinal cord segments (T3 through L3), which was confirmed by MRI and surgically decompressed when required; absence of voluntary micturition for 24 hours despite outside access for 10 minutes 3 times/d; and > 48 hours from the time of spinal cord injury (to allow signs of spinal shock to resolve).[21] Bladders were not manually expressed if dogs had been sedated within the preceding 8 hours or they had concomitant abdominal or pelvic trauma. Sedation included the use of acepromazine, $\alpha_2$-receptor agonists, or butorphanol but not the use of opioids such as buprenorphine, morphine, methadone, or fentanyl, which were used routinely for postoperative analgesia. Unsuccessful manual bladder expressions were recorded.

### Experimental procedures

Data were collected in the morning between 8 AM and 9 AM; manual expression of the bladder had not been performed on any dog since midnight. Dogs were taken for a 10-minute assisted walk prior to attempted manual bladder expression. Bladder expression was performed for up to 2 minutes; urine was expressed into a kidney dish, and the volume of urine expressed was recorded. Each dog was then positioned in right lateral recumbency, and ultrasonography of the bladder was performed. Bladder measurements were recorded as described elsewhere.[19] Estimates of bladder volume were made by use of the following equation[19]: bladder volume = $L \times W \times ([DL + DT]/2) \times 0.625$, where L is longitudinal bladder length, W is transverse bladder width, DL is longitudinal bladder depth, and DT is transverse bladder depth. Intermittent catheterization was then performed. Once urine flow ceased during collection, the catheter was repositioned and collection was attempted for up to another 30 seconds until the operator was confident no more urine could be collected. All procedures (bladder expression, ultrasonography, and bladder catheterization) were performed by a veterinarian or registered veterinary nurse appropriately trained in the procedures.

A monitoring form was used to obtain patient demographic data; urine volumes for manual bladder expression and intermittent catheterization and ultrasonographic bladder measurements were also recorded. Manual bladder expression was performed at 4 PM and midnight, but no data were recorded at those times. This process was repeated for 3 consecutive days for each patient or < 3 days when there was a return of voluntary micturition.

## Statistical analysis

A sample size calculation was performed. Preliminary data collected for 5 dogs (not included in the study reported here) were used to estimate sample size. To detect a significant difference in residual urine volume of 1 mL/kg ($\alpha = 0.05$; power = 80%), it was calculated that 36 dogs would be required to accurately represent the residual urine volume of the population in 95% of cases. Bladder volumes and body weight were not normally distributed (Shapiro-Wilk test); therefore, they were logarithmically (base 10) transformed to achieve normality for linear regression analysis. Descriptive statistics were reported for demographic data and residual urine volume. Standard linear regression and Bland-Altman plots were used to compare estimated bladder volume with actual bladder volume and to compare body weight with efficiency of manual bladder expression. The *F* statistic was calculated for linear regression plots to allow comparison of results with those of previous studies. The *F* statistic estimated the degree to which variation in estimated bladder volume reflected the variation in actual bladder volume. A 2-sample *t* test was used to compare efficiency of manual bladder expression between veterinarians and veterinary nurses. All statistical analyses were performed and figures created with a statistical program.[22,a] All values were reported as mean and SD.

# Results

## Animals

A total of 36 dogs (23 males and 13 females) were included in the study. The most common breed represented was Miniature Dachshund (n = 14). Other breeds included Basset Hound (n = 2), Beagle (2), Border Collie (4), Border Terrier (2), Cocker Spaniel (1), French Bulldog (1), Irish Terrier (1), Jack Russell Terrier (3), Labrador Retriever (1), Lurcher (1), Northern Inuit (1), Shih Tzu (2), and Staffordshire Bull Terrier (1). Body weight ranged from 4 to 35 kg (mean, 14 kg). All injuries were between T3 and L3. Causes of injury included Hansen type 1 disc extrusion (n = 32), fibrocartilaginous embolism (3), and myelitis (1). All Hansen type 1 disc extrusions were surgically decompressed.

## Effectiveness of manual bladder expression

Data for 93 attempts at manual bladder expression were recorded for the 36 dogs (3 days for 25 dogs, 2 days for 7 dogs, and 1 day for 4 dogs, with the latter 11 dogs removed from the study because of improvement in neurologic function and ability to urinate). Some dogs had little variation in residual urine volume following manual bladder expression over all 3 days. However, a substantial number of dogs had marked variation in residual urine volume following manual bladder expression during the study **(Figure 1)**. Because of this observation, separate data points were plotted for each attempt at manual bladder expression. Manual bladder expres-

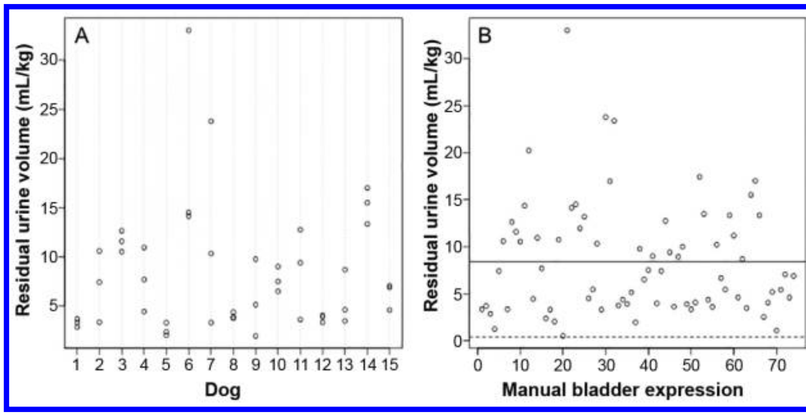


**Figure 1**—Residual urine volume of 15 dogs with acute spinal cord injury following manual bladder expression in the morning (between 8 AM and 9 AM) on each of 3 consecutive days (A) and for each of 74 successful manual bladder expressions in all 36 dogs in the study (B). Each symbol represents results for a successful bladder expression. Residual urine volume was determined by use of intermittent catheterization. In panel A, notice that the variation in residual urine volume across the 3 days was small for some dogs (eg, Nos. 1, 5, 8, and 12) but large for other dogs (eg, Nos. 6, 7, and 11). In panel B, the dashed line represents the upper limit of the residual urine volume for clinically normal dogs following micturition (0.4 mL/kg), and the solid line represents the mean residual urine volume for all dogs in the present study (8.4 mL/kg).

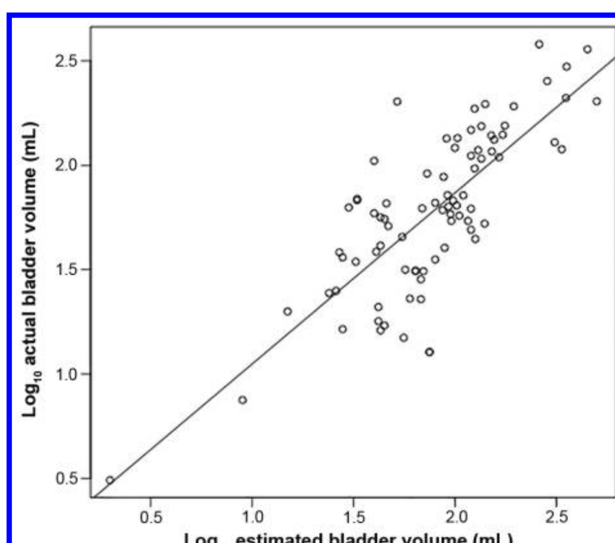


**Figure 2**—Graph depicting the correlation between ultrasonographic estimated bladder volume and actual bladder volume in 36 paraplegic dogs. Each symbol represents results for a successful manual bladder expression. The line of best fit (*R*, 0.79; $R^2$, 0.62; $P < 0.001$) was determined by use of linear regression. Equation for the line was as follows: $\log_{10}$ actual bladder volume = 0.23 + (0.82 X $\log_{10}$ estimated bladder volume).

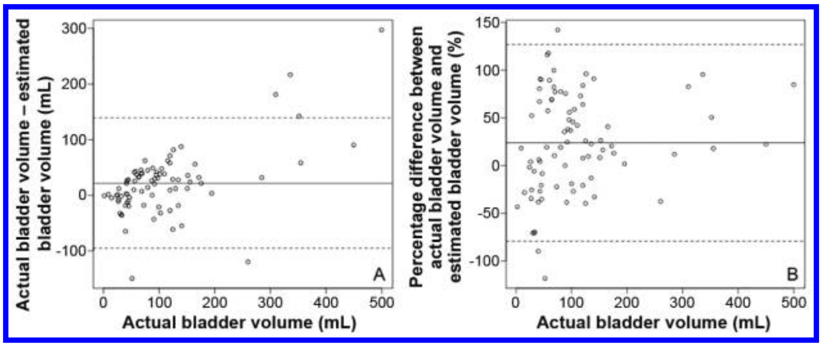


**Figure 3**—Bland-Altman plots of the mean difference (A) and the percentage difference (B) between ultrasonographically estimated bladder volume and actual bladder volume in 36 paraplegic dogs. Each symbol represents results for a successful manual bladder expression. In panels A and B, the solid line represents the mean difference (21.68 mL and 23.76%, respectively) and the dotted lines represent the 95% CI (–95.67 to 139.03 mL and –79.05% to 126.57%, respectively).

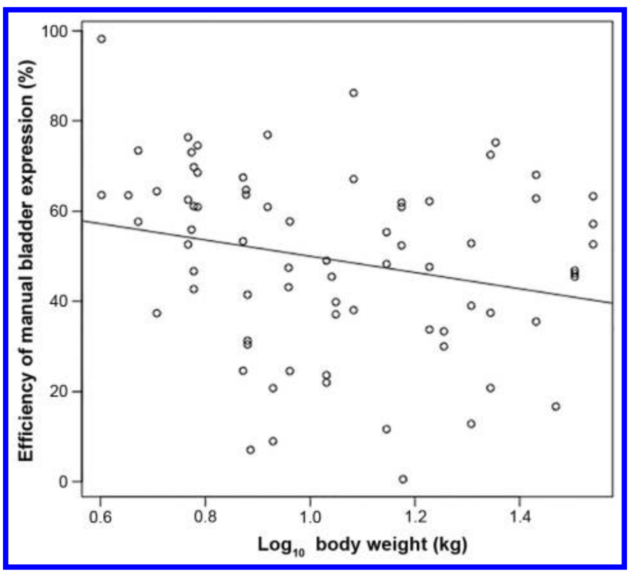


**Figure 4**—Graph depicting the correlation between efficiency of manual bladder expression and body weight in 36 paraplegic dogs. Each symbol represents results for a successful manual bladder expression. The line of best fit (*R*, –0.23; $R^2$, 0.06; *P* = 0.04) was determined by use of linear regression. Equation for the line was as follows: efficiency of manual bladder expression = 68.04 – (18.05 X body weight).

sion failed in 17 of 93 (18.28%) attempts and catheterization failed in 2 of 93 (2.15%) attempts . For 74 successful attempts, mean ± SD residual urine volume following manual bladder expression was 8.41 ± 6.01 mL/kg (range, 0.50 to 33.02 mL/kg). Thus, none of the dogs in the study achieved a physiologically normal residual urine volume (0.2 to 0.4 mL/kg) when managed by manual bladder expression. Mean efficiency of manual bladder expression, defined as the percentage of total urine volume voided by manual bladder expression, was 49.17 ± 20.07% (range, 0.56% to 98.18%). Mean efficiency of manual bladder expression was 53.32 ± 24.99% when performed by veterinary nurses and 43.63 ± 17.72% when performed by veterinarians; there was no significant (*P* = 0.16) difference between these values.

Mean ± SD total bladder volume prior to intervention, as determined by use of intermittent catheterization, was 186 ± 107 mL (range, 34 to 600 mL). This equated to a mean bladder volume of 15.7 ± 9.3 mL/kg.

## Actual versus estimated bladder volume

A linear regression model was used to determine the correlation between estimated bladder volume and actual bladder volume **(Figure 2)**. Results indicated a strong positive correlation (*R*, 0.79 [95% CI, 0.69 to 0.86]; $R^2$, 0.62; $P < 0.001$) between estimated bladder volume and actual bladder volume and that 62% of the variance in actual bladder volume could be attributed to variance in estimated bladder volume. The equation for the regression line was as follows: $\log_{10}$ actual bladder volume = 0.23 (95% CI, –0.05 to 0.50) + 0.82 (95% CI, 0.68 to 0.96) X $\log_{10}$ estimated bladder volume.

A Bland-Altman plot of the same data was used to quantify the agreement between the 2 methods for determining bladder volume[23] **(Figure 3)**. Typically, estimated bladder volume underestimated actual bladder volume by 21.68 mL (95% CI, –95.67 to 139.03 mL). Estimated bladder volume appeared to have greater variation than actual bladder volume at higher urine volumes. To investigate this finding further, a second Bland-Altman plot was constructed with percentage differences (mean difference, 23.76%; 95% CI, –79.05% to 126.57%). This indicated that there was a similar degree of variation in bladder volumes across all urine volumes, which had a greater effect on the estimated volume at higher values.

## Manual bladder expression in large dogs

To investigate the commonly held belief that manual bladder expression would be more difficult and therefore less effective in large dogs, a linear regression model was constructed that compared body weight with manual bladder expression efficiency **(Figure 4)**. Results indicated that there was no correlation (*R*, –0.23 [95% CI, –0.44 to –0.01]; $R^2$, 0.06; *P* = 0.04) between these 2 variables and that only 4% of the variation in manual bladder expression efficiency could be attributed to body weight. The equation for the regression line was as follows: manual bladder expression = 68.04 (95% CI, 49.69 to 86.38) – 18.05 (95% CI, –35.05 to –1.04) X body weight.

# Discussion

Manual bladder expression was ineffective at fully emptying the bladder in paraplegic dogs because a physiologically normal residual urine volume was not achieved for any of the 93 manual bladder expression attempts. The 76 successful attempts typically resulted in 49% of the total urine volume being voided from the bladder by use of this technique. This likely would eliminate the risk of detrusor atony attributable to any increase in bladder pressure, but it is not known whether leaving a higher than physiologically normal residual urine volume within the bladder would predispose dogs to urinary tract infection. Investigators of 2 studies[9,15] found no increase in the risk of urinary tract infection in dogs managed with manual bladder expression following spinal cord injury, but it appears logical that leaving urine in the bladder may predispose to infection. Difficulties of manual bladder expression in the group of dogs reported here was likely attributable to the lack of supraspinal control that led to an upper motor neuron bladder.

Manual bladder expression was completely unsuccessful in 17 of 93 (18.3%) attempts. Most times, manual bladder expression was successful on the subsequent day of the study; however, on the day of a failed attempt, an alternative method for emptying the bladder was required. Manual bladder expression was unsuccessful on all 3 days of the study for 3 of 36 dogs. Body weight of these 3 dogs (17.4, 24.5, and 28.8 kg) was more than the mean weight for the entire study population (14 kg). Despite these findings, there was no correlation between efficiency of manual bladder expression and body weight. A stronger correlation between these variables would have been expected if manual bladder expression was less effective in larger dogs. We concluded that if manual bladder expression was successful, it was equally effective in small and large dogs. Complete failure of manual bladder expression may be more likely in larger dogs, but a larger cohort that includes more dogs in which manual bladder expression failed would be needed to support this hypothesis.

Pharmacological treatments may increase the efficiency of manual bladder expression from the 49% for the population of the study reported here. Results of the present study can be used as a benchmark for efficacy of this procedure in paraplegic dogs; thus, improvements afforded by drugs could be investigated to determine whether their use in such patients would be recommended. Although we enrolled dogs with acute spinal cord injury in the present study, the findings would likely be useful for the management of dogs with chronic spinal cord injury, which are often managed at home with manual bladder expression provided by their owners. Parasympathomimetic compounds, such as carbachol and bethanechol, have been used to improve bladder voiding, but there is little information available on clinical efficacy.[24] Alternatively, blockade of α-adrenergic receptors with sympatholytic compounds (eg, prazosin or phenoxybenzamine) aimed at causing urethral sphincter relaxation and used in combination with parasympathomimetic compounds could be advantageous when dealing with an upper motor neuron bladder.[25–27]

A sacral nerve root stimulator has provided efficient bladder emptying in dogs with spinal cord injury and is indicated for use in chronically incontinent dogs.[28] At 3 weeks after implantation, 8 of 9 dogs had a voiding efficiency ranging from 92% to 99%, which is a clear improvement on the mean of 49% achieved with manual bladder expression in the study reported here. This neuroprosthesis, which is surgically placed on the extradural sacral nerve root, has been available to stimulate bladder voiding in paraplegic humans since the 1980s.[29,30]

Ultrasonographic estimation of bladder volume is common practice in human medicine.[17] This previously has been performed with conventional 2-D ultrasonography, as was performed in the present study. Results for canine patients have resulted in advocacy for the use of conventional 2-D ultrasonographic bladder measurements for determining urine volume, and a strong correlation was found between estimated and actual bladder volumes in 1 study.[18] When comparing the accuracy of 2 procedures, it has been highlighted in the medical literature that agreement between 2 methods is more important than their correlation[23] because 2 values can have a perfect correlation, even when one method consistently underestimates or overestimates the value obtained for the second method. In the study reported here, we used the same method described in another study[19] to estimate bladder volumes by use of ultrasonography and, similar to results of that study,[19] found a strong correlation with actual bladder volumes. However, in that study,[19] investigators used the same collection method on healthy dogs. Furthermore, in the study reported here, we also assessed the agreement between estimated bladder volume and actual bladder volume by use of Bland-Altman plots and found that the estimated bladder volume consistently underestimated the actual bladder volume by a mean of 21.68 mL. We decided this was a clinically acceptable estimation, but values for the 95% CI were unacceptably wide (–95.67 to 139.03 mL), although similar to those determined for humans by use of the same technique.[31,32] Considering that the bladder of an 11-kg dog is thought to be able to hold approximately 100 to 120 mL of urine without overt bladder distension,[33] narrower CI values would be needed for ultrasonographic bladder estimates to be useful. Larger sample sizes yield a more precise sample statistic and therefore typically result in smaller values for the CI; however, if there is a high degree of variability in the measurement, these values for the CI may still be too wide for clinical use. Most of the variability in bladder volume estimates in the present study could have been attributable to the patients, ultrasound machine (although the same machine was used for all dogs), or operator. Repeated measurements of the same dog at the same time point by multiple operators would have allowed assessment of interobserver reliability. Ultrasonographic estimates determined by diagnostic imaging specialists may limit variability for the procedure; however, this would not be practical for day-to-day management of these patients. Thus, measurements in the present study were obtained by attending veterinarians or veterinary nurses to ensure the results were clinically applicable and represented the real-life situation of a busy neurology service.

In human medicine, estimates of bladder volume have been determined by use of planimetric 3-D volumetric measurements obtained with a portable ultrasonographic bladder-scanning device,[b] which has been used for > 20 years.[16] This method provides a much more accurate estimate of bladder volume, with a mean difference of 41 mL (95% CI, 26 to 55 mL).[34] To the authors' knowledge, this or a similar device has not yet been tested in canine patients and warrants further investigation.

In the present study, manual bladder expression performed by a trained veterinarian or veterinary nurse voided approximately half of the total bladder volume. There was a strong correlation between estimated bladder volume (determined on the basis of 4 ultrasonographic measurements) and actual bladder volume, with good agreement (mean difference, −22 mL). However, the CI for this estimation (−95.67 to 139.03 mL) was unacceptably wide, which indicated that estimates must be interpreted with caution. Increasing body weight did not influence the effectiveness of manual bladder expression.

## Footnotes

a. The R, version 3.1.3, R Foundation for Statistical Computing, Vienna, Austria. Available at: www.R-project.org. Accessed Feb 1, 2016.
b. BladderScan, Diagnostic Ultrasound, Bothell, Wash.

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