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The effectiveness of manual bladder expression in paraplegic dogs

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Abstract

Objective To determine the effectiveness of manual bladder expression in paraplegic dogs whilst comparing urine volumes measured by intermittent catheterization and ultrasound.

Sample Ninety-three bladder volume measurements were prospectively collected from 36 paraplegic dogs.

Procedures Residual urine volume was determined by intermittent urethral catheterization and ultrasound estimation.

Results On average, manual bladder expression voids 49% of urine from the bladder in this population of dogs. There is no correlation between the effectiveness of manual bladder expression and body weight (R2 0.06). Ultrasonographic estimation of bladder volume shows good correlation (R2 0.62) but clinically unacceptable variation in predicting actual bladder volumes (Mean difference, 22 mL; CI, -96 to 139 mL).

Conclusions and Clinical Relevance Manual bladder expression is ineffective at completely emptying the bladder of urine but the effectiveness of the procedure is not affected by body weight. It is still likely to be a useful procedure to prevent a build-up in pressure within the bladder. On average ultrasonographic estimation of bladder volume can be a useful predictor of actual bladder volume but is susceptible to wide variations for individual cases and so should be interpreted with a degree of caution.

Introduction

Normal 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 supra-spinal centres via the spinal cord. Spinal cord injury in the thoracolumbar region leads to an upper motor neuron bladder and eventually bladder dyssynergia.[5] Initially the lack of afferent information on bladder fullness to the brain leads to prolonged urine retention and the preservation of sacral spinal reflexes below the lesion in turn causes persistence of urethral tone. As the 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. More than two weeks following severe spinal cord injury, involuntary detrusor contractions begin during the filling phase, causing reflex incontinence.[6,7] However, these involuntary detrusor contractions, without supra-spinal control, are not enough to completely void 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 lead to incomplete voiding of urine from the bladder.[5]

The methods for managing bladder dysfunction in spinal cord injury (manual expression, indwelling catheterization or intermittent catheterization) aim to frequently remove urine from the bladder to prevent prolonged urine retention.[8] Ideally these techniques should leave the same residual urine volume as in normal dogs, i.e. 0.2 to 0.4 mL/kg.[9] Indwelling catheterisation allows efficient urine evacuation with minimal intervention once a catheter is placed. Unfortunately placement of a urinary catheter can damage the bladder or urethra and the risk of urinary tract infection increases daily with this technique, which can discourage its use.[10-12] Intermittent catheterisation can be time consuming, particularly in female dogs whereas manual bladder expression is thought to be quick and easy to perform in small breed dogs but can be difficult in large, obese or aggressive dogs. As nothing is passed along the urethra the theoretical risk of urinary tract infection may be lower than with catheter based methods, but this is yet to be demonstrated. Nevertheless, 21% to 38% of spinal cord injured dogs managed with manual bladder expression still develop a urinary tract infection.[8,13,14] It is possible that if a larger residual urine volume is left in the bladder it may increase the risk of urinary tract infection (e.g. by increasing the bladder's exposure to uropathogens which are normally rapidly and efficiently cleared from the bladder) and the risk of detrusor atony. Currently, despite its widespread clinical use, it is unknown how effective manual bladder expression is at emptying the bladder. Accurate data on the effectiveness of current bladder management techniques would allow objective comparisons to be made with new therapies or techniques.

The gold standard for accurately measuring the residual urine volume requires intermittent catheterisation.[15] Ultrasonographic estimation of the residual urine volume is standard practice on human hospital wards to determine if bladder management is required, avoiding the invasive and time-consuming procedure of intermittent catheterisation.[16] It is used in our clinic by appropriately trained veterinary surgeons and registered veterinary nurses for the same purpose. We currently use the bladder diameter as a rough guide of bladder volume to decide if an intervention (e.g. intermittent catheterisation, indwelling catheterisation or manual bladder expression) is required. Previous research in dogs has found that bladder volume can be accurately estimated from a few simple ultrasonographic measurements using a specific formula.[17-19]

The primary aim of this study was to determine how effective manual bladder expression was at emptying the bladder in paraplegic dogs with an upper motor neuron bladder by measuring the residual urine volume following manual bladder expression. Additionally we investigated whether body weight correlated with this residual urine volume to explore the commonly held belief that manual bladder expression is less effective in larger breed dogs. Finally we have tested ultrasonographic bladder volume estimates in a clinically applicable setting with conscious paraplegic dogs to determine whether estimates of these bladder volumes correlate and agree with actual bladder volumes.

Materials and Methods

The study population was prospectively recruited from client owned dogs presenting to a specialist neurology referral service in the United Kingdom, with naturally occurring spinal cord injury between October 2013 and March 2014. The details of the study were explained to dog owners during the initial consultation and informed written consent was obtained before any dog was included in the study. The study design was approved by the local ethical committee and granted a veterinary investigation number (VIN/13/037).

Inclusion criteria for the study included: (1) acute (within 7 days) paraplegia with or without pelvic limb pain sensation that was secondary to a spinal cord injury between the third thoracic and third lumbar spinal cord segments (T3-L3), which was confirmed by MRI and surgically decompressed where required (2) absence of voluntary micturition for 24 hours despite access to outside for 10 minutes three times a day; and (3) more than 48 hours from the time of spinal cord injury (to allow any signs of spinal shock to have resolved).[20] Dogs were not manually expressed if they had been sedated in the last 8 hours; or they had concomitant abdominal or pelvic trauma. Sedation refers to the use of acepromazine, alpha-2 agonists or butorphanol. It does not refer to the use of opiods such as buprenorphine, morhpine, methadone or fentanyl which were used routinely for post operative analgesia. Any patients in which manual bladder expression was unsuccessful were recorded.

Data was collected in the morning between 8am and 9am and all dogs had not been manually expressed 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 into a kidney dish, with the volume of urine produced recorded. Ultrasound of the bladder with the patient in right lateral recumbency was then performed and bladder measurements were recorded as described by Atalan *et al*.[18] This included the longitudinal bladder length (L) and depth (DL) and the transverse bladder width (W) and depth (DT). Estimates of bladder volume were made using the formula from this study where bladder volume = L x W x (DL + DT / 2) x 0.625. Intermittent catheterisation was then performed and once urine flow ceased during collection the catheter was repositioned for less than thirty seconds until the operator was confident no more urine could be collected. All procedures (bladder expression, ultrasound and catheterisation) were carried out by a veterinary surgeon or a registered veterinary nurse appropriately trained in the procedure. Using a prepared monitoring form, patient demographic data was recorded along with urine volumes from manual bladder expression plus intermittent catheterisation and ultrasonographic bladder measurements. After data collection between 8am and 9am, bladders were then manually expressed at 4pm and 12am and no further recordings were taken that day. This process was repeated for three consecutive days for each patient or less than three days if there was a return of voluntary micturition.

Statistical analysis

A sample size calculation was performed in order to detect a significant difference of 1 mL/kg in residual urine volume with a power of 80%. Preliminary data collected from 5 dogs (not used in the reported data here) was used to estimate sample statistics. Alpha was set at 0.05. It was calculated that 36 dogs were required for sample data to accurately represent the residual urine volume of the population in 95% of cases. Bladder volumes and body weight were not normally distributed (based on Shapiro-Wilks test) and so were log10 transformed to achieve normality for linear regression analysis. Descriptive statistics were presented for demographic data and the residual urine volume. Standard linear regression and Bland-Altman plots were used to compare estimated bladder volume with actual bladder volume and body weight with efficiency of manual bladder expression. The F-statistic was calculated for linear regression plots to allow comparisons to be made with previous studies. The F-statistic estimates the degree to which variation in estimated bladder volume reflects the variation in actual bladder volume. A two sample t-test was used to compare the efficiency of manual bladder expression between vets and nurses. All statistical analyses and figures were performed in R[a,21]. All values are presented as mean (standard deviation).

Results

Demographic data

Of the 36 dogs included in the study 23 were male and 13 were female. The most common breed represented was the Miniature Dachshund (14) but other breeds included the Basset Hound (2), Beagle (1), Border Collie (4), Border Terrier (1), Cocker Spaniel (1), French Bulldog (1), Irish Terrier (1), Jack Russell Terrier (1), Labrador Retriever (1), Northern Inuit (1), Shih Tzu (2), Staffordshire Bull Terrier (1) and cross breed (1). Body weight ranged from 4kg to 35kg with a mean of 14kg. All injuries were between T3-L3 and causes of injury included Hansen type 1 disc extrusion (32), fibrocartilaginous embolism (3) and myelitis (1). All Hansen type 1 disc extrusions underwent surgical decompression (32).

Effectiveness of manual bladder expression

There were a total of 93 attempts at manual bladder expression in 36 dogs, with 7 dogs providing 2 data points and 4 dogs providing 1 data point due to improvement in neurological function and therefore removal from the study. A proportion of cases showed little variation in residual urine volume following manual bladder expression across the three days of sampling. However, a significant proportion of cases showed marked variation in residual urine volume following manual bladder expression during the study (Figure 1a). Based on this observation, separate data points were plotted for each attempt at manual bladder expression (Figure 1b). Manual bladder expression failed in 17 out of 93 (18.28%) attempts. Excluding failed attempts, the mean residual urine volume following manual bladder expression was 8.41 (6.01) mL/kg with values ranging from 0.50 to 33.02 mL/kg. This reveals that none of the dogs in this study achieved a normal residual urine volume (0.2 - 0.4 mL/kg) when managed by manual bladder expression. The efficiency of manual bladder expression, defined as the percentage of total of urine volume voided by manual bladder expression, was 49.17 (20.07) % with values ranging from 0.56% to 98.18%. The mean value was 53.32 (24.99) % when performed by nurses and 43.63 (17.72) % when performed by veterinary surgeons. There was no significant difference between these values (p=0.16).

The mean total bladder volume, prior to intervention, as determined by intermittent catheterisation, was 186 (107) mL, ranging from 34 mL to 600 mL. This data equates to a mean bladder volume of 15.7 (9.3) mL/kg.

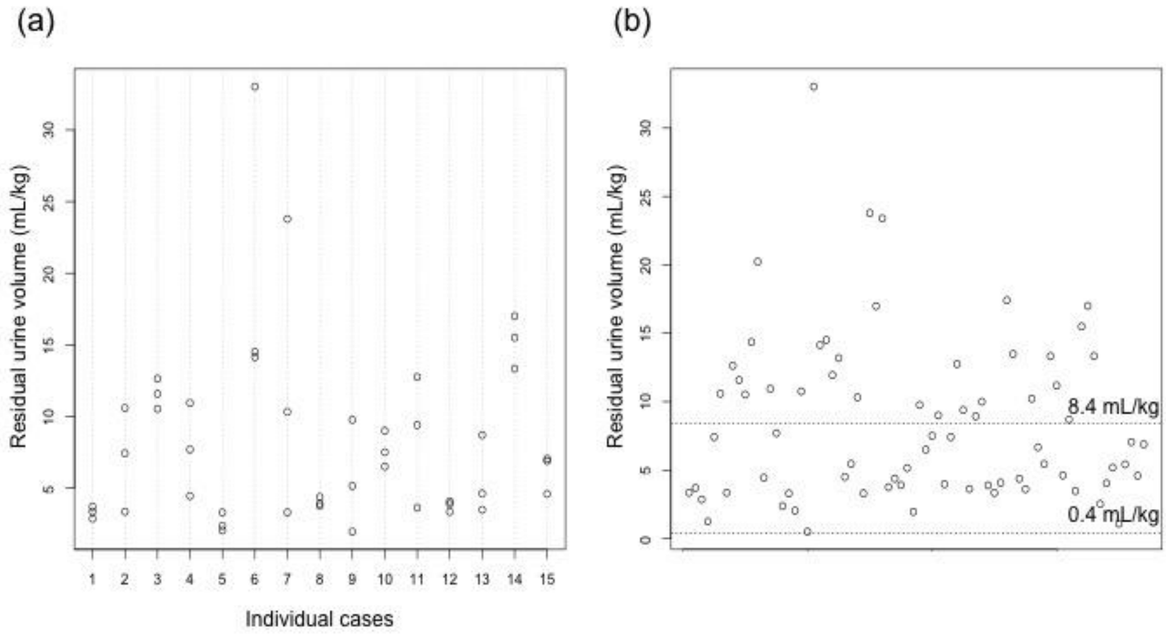

Figure 1: Residual urine volume of dogs with acute spinal cord injury following manual bladder expression. (a) Each point on the x-axis represents a single case enrolled in the study for which there were three data points collected. The variation in residual urine volume during the three days of sampling was small for some cases (e.g. Case 1, 5, 8 and 12) but large for other cases (e.g. Case 6, 7, 11). (b) Each point represents a successful attempt at manual bladder expression. The dashed line at 0.4 mL/kg represents the upper limit of the residual urine volume for normal dogs following micturition. The dashed line at 8.4 mL/kg represents the mean residual urine volume of all cases.

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). R, 0.79 (CI, 0.69 to 0.86), R2, 0.62, F-statistic, 128.9, p=2.2x10-16. This shows that there was a strong positive correlation between estimated bladder volume and actual bladder volume and that 62% of the variance in actual bladder volume can be attributed to the variance in estimated bladder volume. Regression equation; actual bladder volume=0.23 (CI, -0.05 to 0.50) + 0.82 (CI, 0.68 to 0.96) x estimated bladder volume.

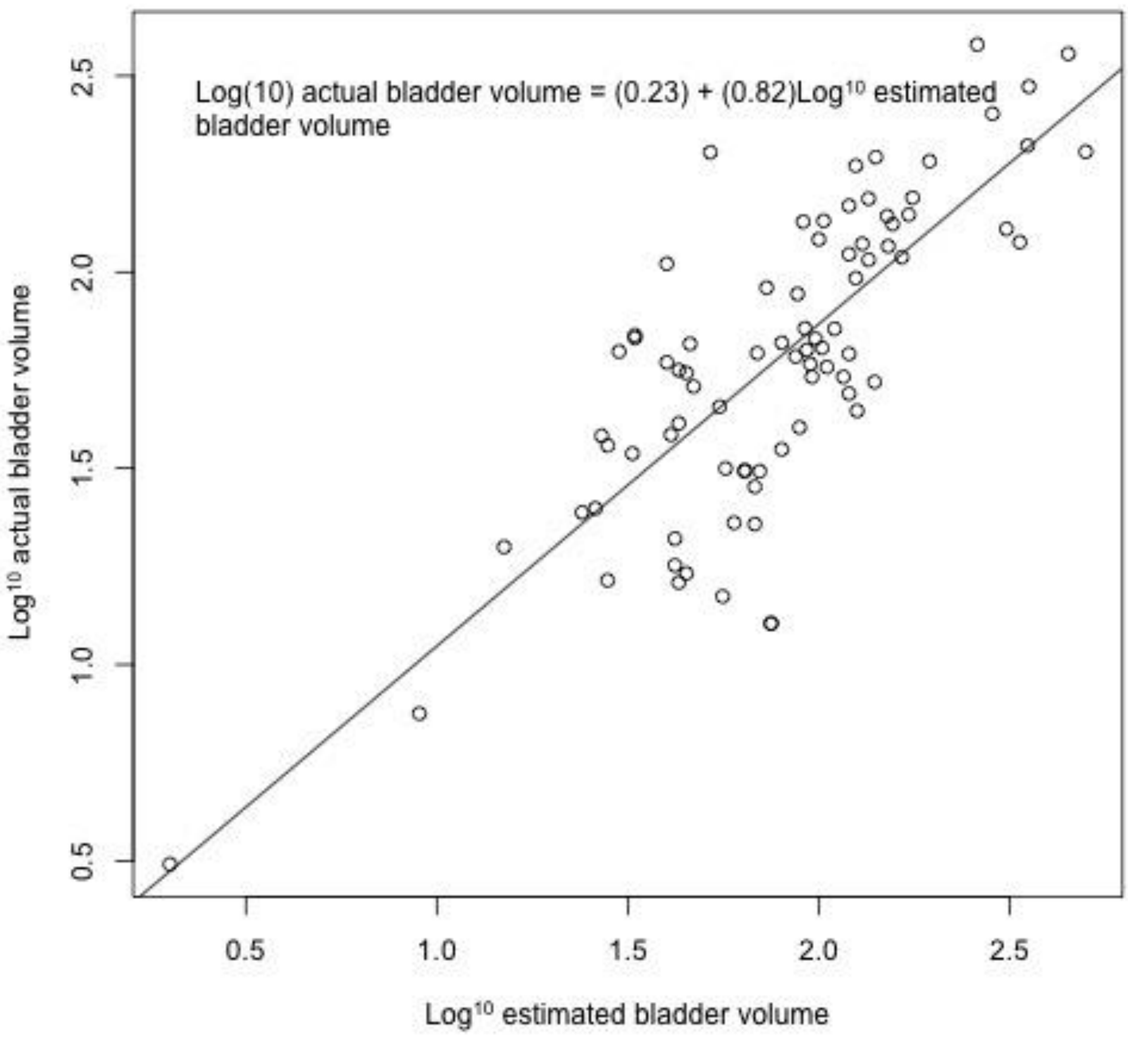

Figure 2: Correlation between ultrasonographic estimated bladder volume and actual bladder volume. Line of best fit by linear regression and regression equation are shown (R, 0.79, R2, 0.62, F-statistic, 128.9, p<0.001).

A Bland-Altman plot of this same data was used to quantify the level of agreement between the two sampling methods[29] (Figure 3a). On average the estimated bladder volume underestimates the actual bladder volume by 21.68 mL (mean difference, 21.68) with a confidence interval of -95.67 to 139.03 mL. The estimated bladder volume appears to show greater variation from the actual bladder volume at higher urine volumes. To investigate this finding further a second Bland-Altman plot was constructed using the percentage of differences (Figure 3b). Mean difference, 23.76 %, confidence interval of -79.05 to 126.57 %. This showed that there was similar degree of variation in bladder volumes across all volumes but this had a greater effect on the estimated volume at higher values.

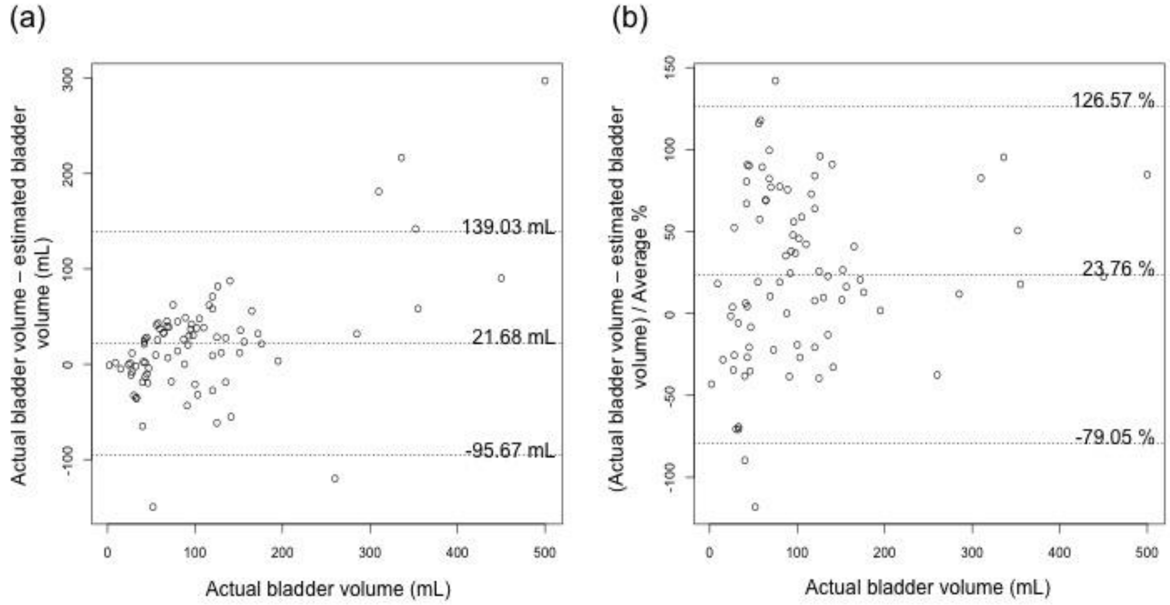

Figure 3: Agreement between ultrasonographic bladder volume and actual bladder volume. (a) Bland-Altman plot of the difference between the two measurements (y-axis) against actual bladder volume (x-axis). Dotted lines represent the mean +/- 95% confidence intervals. (b) Bland-Altman plot comparing the percentage difference between the two measurements (y-axis) against actual bladder volume (x-axis). Dotted lines represent the mean +/- 95% confidence intervals.

Manual bladder expression in large dogs

To investigate the commonly held belief that manual bladder expression is more difficult and therefore less effective in larger dogs a linear regression model was constructed to compare body weight with manual bladder expression efficiency (Figure 4). R, -0.23 (CI, -0.44 to -0.01), R2, 0.06, p=0.04. This shows that there was no correlation between these two variables and that only 4% of the variation in manual bladder expression efficiency can be attributed to body weight. Regression equation; manual bladder expression=68.04 (CI, 49.69 to 86.38) – 18.05 (CI, -35.05 to -1.04) x body weight.

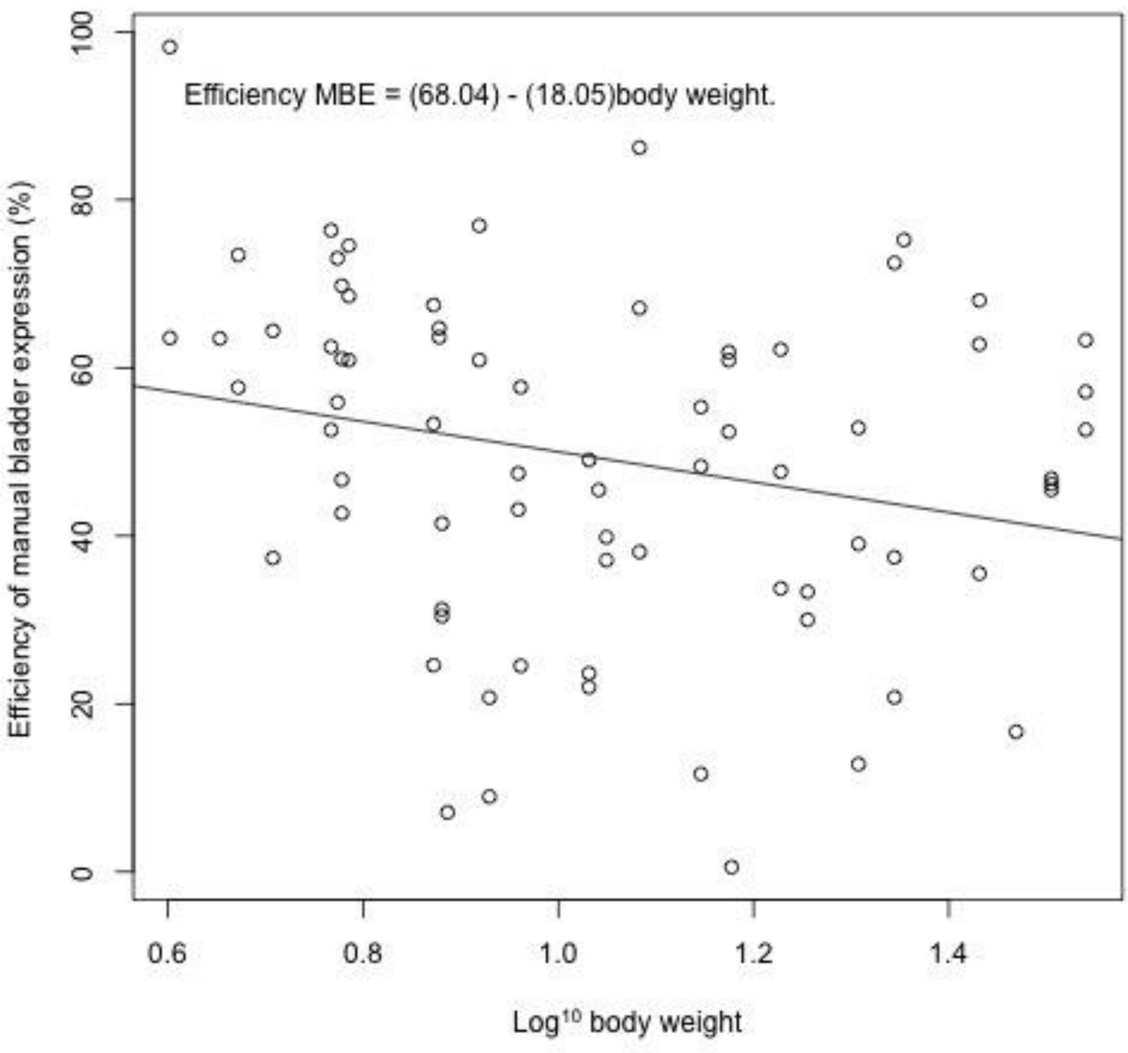

Figure 4: Correlation between the efficiency of manual bladder expression and body weight. Line of best fit by linear regression and the regression equation are shown (R= -0.23, R2= 0.06, F-statistic= 4.33, $p<0.05$).

Discussion

Manual bladder expression was ineffective at fully emptying the bladder in paraplegic dogs, because a normal residual urine volume was not achieved in any of the 93 manual bladder expression attempts. Excluding failed attempts at manual bladder expression, on average 49% of the total urine volume was voided from the bladder using this technique. This is likely to eliminate the risk of detrusor atony due to any increase in bladder pressure but we do not know whether leaving a higher than physiologically normal residual urine volume within the bladder will predispose dogs to urinary tract infection. Two separate studies found no increase in the risk of urinary tract infection in dogs managed with manual bladder expression following SCI[8,14] but it seems logical that leaving urine in the bladder may predispose to infection. The difficulties in manual bladder expression found in this group of dogs is likely due to lack of supra-spinal control leading to an upper motor neuron bladder.

Manual bladder expression was completely unsuccessful 18% of the time. On most occasions manual bladder expression was successful on the next day of the study but on the day of failure an alternative method for emptying the bladder was required. Manual bladder expression failed on every study day in 3 out of the 36 cases enrolled. These cases all weighed more than the mean weight of 14 kg for the study group (17.4, 24.5 and 28.8 kg). Despite these findings there was no correlation between the efficiency of manual bladder expression and body weight (Figure 4). We would have expected a stronger correlation between these variables if manual bladder expression was less effective in larger breed dogs. We conclude that if manual bladder expression is successful it is equally effective in small and large breed dogs. However complete failure of manual bladder expression may be more likely in larger breed dogs, but a larger cohort to include more failed cases would be needed to support this hypothesis.

Pharmacological therapies may increase the efficiency of manual bladder expression from 49% in this group of cases. Now that there is a benchmark for the efficacy of this procedure in paraplegic dogs, further research into the improvement afforded by drugs could be investigated to determine whether there use in the this setting is recommended. Although this study enrolled dogs with acute spinal cord injury, the findings are likely to be useful for the management of dogs with chronic spinal cord injury, which are often managed at home by their owners with manual bladder expression. Parasympathomimmetic compounds, such as carbachol and bethanecol are sometimes used for this purpose with little published clinical efficacy currently available.[22] Alternatively, alpha-adrenergic blockade with sympatholytic compounds such as prazosin or phenoxybenzamine aiming to cause urethral sphincter relaxation to be used in combination with parasympathomimmetic compounds could be advantageous when dealing with an upper motor neuron bladder.[23-25]

A sacral nerve root stimulator is available for efficient bladder emptying in dogs with spinal cord injury and indicated for chronically incontinent dogs.[26] At 3 weeks after implantation, 8 out of 9 dogs had a voiding efficiency ranging from 92–99%, a clear improvement on the mean of 49% achieved in this study with manual bladder expression. This neuroprosthesis is placed surgically on extradural sacral nerve root and has been available to paraplegic people to stimulate bladder voiding since the eighties.[27,28]

Ultrasonographic estimation of bladder volume is common practice in the medical profession.[16] Previously this was done using conventional two-dimensional ultrasound, as presented in this study. Previous research in canine patients has advocated the use of conventional two-dimensional ultrasonographic bladder measurements for determining urine volume and a strong correlation was found between estimated and actual bladder volumes.[17] When comparing the accuracy of any two procedures it has been highlighted in the medical literature that agreement between two measures is more important than their correlation.[29] As two values can have a perfect correlation even if one value consistently underestimates or overestimates the other. We used the same method described by Atalan *et al*[18] to estimate bladder volumes using ultrasound and also found a strong correlation with actual bladder volumes, R2=0.62, F-statistic=128.9 (Figure 2). Atalan *et al*[18] achieved a similar F-statistic of 100.7 using the same collection method in healthy dogs. However, we also assessed the agreement between estimated bladder volume and actual bladder volume using Bland-Altman plots and found that the estimated bladder volume consistently underestimates the actual bladder volume by an average of 21.68 mL (Figure 3a). We decided this was a clinically acceptable estimation but the values for the 95% confidence intervals were unacceptably wide in our study (-95.67 to 139.03 mL), similar to those found in people using the same technique.[30,31] Considering an 11kg dog is thought to be able to hold around 100 to 120 mL of urine without overt bladder distension,[32] these confidence interval values would need to be narrower for ultrasonographic bladder estimates to be useful. Larger sample sizes give a more precise sample statistic and therefore tend to result in smaller values for the confidence interval; however, if there is a high degree of variability in the measurement, even with large sample sizes, these values for the confidence interval may still be too wide for clinical use. The majority of variability in bladder volume estimates in this study could arise from the subjects, the ultrasound machine (although the same machine was used) or the operator. Repeated measurements of the same dog at the same time point by different users would have allowed inter-observer reliability to be assessed. Having ultrasonographic estimates performed by imaging specialists may limit the variability in the procedure, however, this would not be practical for the day to day management of these cases and so measurements were performed by attending clinicians or trained veterinary nurses in order for any findings to be more clinically applicable and represent the 'real-life' situation of a busy neurology service. In the medical profession bladder volume estimates have been collected using planimetric three-dimensional volumetric measurements using a BladderScan device[b] for more than 20 years (for a review see, Kelly[15]). This provides a much more accurate estimate of bladder volume with a mean difference of 41mL and confidence intervals between 26 – 55 mL.[33] As far as the Authors are aware this technology has not yet been tested in canine patients and warrants further investigation.

Conclusion

Manual bladder expression voids around 50% of the total bladder volume when performed by trained veterinary nurses or clinicians.

There is a strong correlation between estimated bladder volume based on 4 ultrasound measurements and actual bladder volume with good agreement (mean difference -22 mL). However, the confidence intervals of this estimation are unacceptably wide (-95.67 to 139.03 mL), meaning estimates must be interpreted with caution.

Increasing body weight does not influence the effectiveness of manual bladder expression.

Footnotes

a. R foundation for Statistical computing, Vienna, Austria. http://R-project.org.

b. Diagnostic Ultrasound, Bothell, WA.

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