

Evaluation of a selective neurectomy model for low urethral pressure incontinence in female dogs

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Objective—To develop a model of low urethral pressure incontinence and compare the relative contributions of the pudendal and hypogastric nerves with urethral function by performing selective neurectomy and ovariectomy in dogs.

Animals—19 healthy Foxhounds.

Procedure—Dogs were allocated into 2 groups. The first group (10 dogs) underwent bilateral hypogastric neurectomy and ovariectomy and subsequent bilateral pudendal neurectomy. The second group (9 dogs) underwent bilateral pudendal neurectomy and subsequent hypogastric neurectomy and ovariectomy. Urethral pressure profilometry and leak point pressure (LPP) tests were performed before and after each neurectomy.

Results—Before surgery, mean \pm SD LPP and maximal urethral closure pressure (MUCP) in all dogs were 169.3 ± 24.9 cm H₂O and 108.3 ± 19.3 cm H₂O, respectively; these values decreased to 92.3 ± 27 cm H₂O and 60.7 ± 20.0 cm H₂O, respectively, after both selective neurectomy surgeries. There was a progressive decline of LPP after each neurectomy; however, MUCP decreased only after pudendal neurectomy. Fifteen dogs had mild clinical signs of urinary incontinence. All dogs appeared to have normal bladder function as indicated by posturing to void and consciously voiding a full stream of urine. Urinary tract infection did not develop in any dog.

Conclusions and Clinical Relevance—Hypogastric and pudendal neurectomy and ovariectomy caused a maximum decrease in LPP, whereas pudendal neurectomy caused a maximum decrease in MUCP.

Impact on Human Medicine—This model may be useful for evaluation of treatments for improving urinary control in postmenopausal women. (*Am J Vet Res* 2005;66:695–699)

The prevalence of urinary incontinence increases with age in humans¹ and female dogs.^{2,4} Prevalence, clinical signs, and recommended treatments of stress incontinence in postmenopausal women are well documented.¹ Because dogs that have undergone ovario-

hysterectomy (spayed) can develop urinary incontinence,^{3,6} we investigated similarities between urethral dysfunction in a selective neurectomy model in spayed female dogs and urethral dysfunction that may develop naturally in women and spayed dogs.

Urethral outflow resistance is caused by the external urethral sphincter, which is composed of skeletal muscles innervated by somatic nerves and of smooth muscles innervated by sympathetic nerves.^{7,8} On the basis of results of anatomic and electrophysiologic studies,⁷ severing the urethral branch of the pudendal nerve to the skeletal muscles of the urethral sphincter should decrease urethral closure pressures. A nearly complete sympathectomy can be performed by incising the hypogastric nerve distal to the caudal mesenteric plexus.⁷ The purpose of the study reported here was to develop a model of low urethral pressure incontinence and compare the relative contributions of the pudendal and hypogastric nerves with urethral function, as measured by urethral pressure profilometry (UPP) and leak point pressure (LPP), by performing selective neurectomy and ovariectomy in dogs.

Materials and Methods

Dogs—Nineteen commercially reared sexually intact female Foxhounds were used in this study, which was approved by the University of Georgia Laboratory Animal Care and Use Committee. Dogs were ≥ 1 year old; mean \pm SD weight was 25.4 ± 2.0 kg (range, 21.6 to 29.0 kg).

Surgical model—Selective neurectomies were performed in 2 groups of dogs in a crossover experimental design. Bilateral resection of the hypogastric nerve and ovariohysterectomy were performed as a first-stage surgery in 10 dogs (group 1); those dogs were studied for ≥ 2 months before the pudendal nerves were bilaterally resected. Bilateral resection of the pudendal nerves was performed as a first-stage surgery in 9 dogs (group 2); those dogs were studied for ≥ 2 months before hypogastric nerves were bilaterally resected and ovariohysterectomy was performed. The crossover design provided comparisons of the relative contributions of sympathetic innervation via the hypogastric nerves to that of somatic innervation via the pudendal nerves. The anesthetic protocol for both surgeries was the same. Atropine (0.05 mg/kg, IM), acepromazine (0.1 mg/kg, IM), and butor-

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phanol (0.2 mg/kg, IM) were administered as preanesthetics. Anesthesia was induced with thiopental sodium (12 mg/kg, IV to effect) and maintained with isoflurane. The same dosage of butorphanol was given at the end of surgery and 4 hours later.

Neurectomy of the pudendal nerves was performed through bilateral curved incisions ventral and lateral to the anus, similar to surgical repair of perineal hernias in dogs. Dogs were positioned in ventral recumbency with their head down. Surgical magnification was used. The pudendal nerve was identified at the level of the branching of the caudal rectal nerve. A 1-cm length of the urethral branch of the pudendal nerve was removed from between ligatures distal to the branching of the caudal rectal nerve in an effort to preserve innervation to the external anal sphincter. Surgical sites were closed with interrupted sutures of 3-0 polydioxanone in 2 subcutaneous layers, and interrupted cruciate sutures of 3-0 nylon were placed in the skin.

A caudal midline laparotomy was performed for the ovariohysterectomy and selective neurectomy of the hypogastric nerves. Both ovaries and the uterus were removed to within 1 cm of the cervix. One-centimeter portions of the hypogastric nerves were excised just distal to the caudal mesenteric plexus. The abdomen was closed with simple continuous size-0 polydioxanone sutures in the external sheath of the rectus abdominus muscle, simple continuous 3-0 polydioxanone sutures in the subcutaneous tissue, and interrupted cruciate sutures of 3-0 nylon in the skin. Tissue from all neurectomy sites was examined histologically and confirmed to be nerve tissue in each dog.

Clinical and urodynamic evaluations—Evaluations performed before surgery included physical examinations, CBC, serum biochemical analyses, an antigen test for *Dirofilaria immitis*, urinalysis, observation of urination, determination of residual volume after urination by catheterization, and UPP and LPP tests. Urine for microbial culture was obtained via cystocentesis. These are standard procedures in our urodynamic laboratory and have been described in previous publications.^{6,9,10} All urodynamic studies were performed before the first surgery and after the second surgery. Three urodynamic studies (UPP, residual volume, and LPP) were performed before and at 2, 4, and 6 weeks after each surgery. Recordings for UPP and LPP were performed by use of a computer-based urodynamic system.³ Dogs were given ampicillin (500 mg, PO) before each procedure requiring catheterization of the urinary bladder. Care was also taken to be as aseptic as possible, and only sterile catheters were used. Urinalysis was performed on samples obtained by either centesis or a catheter before each urodynamic session. Urination was monitored closely and videotaped before and after each surgery.

Urethral pressure profile tests were performed in conscious dogs during gentle restraint in right lateral recumbency.^{6,9} An 8-F, single-lumen UPP catheter^b was placed aseptically through the urethra into the urinary bladder and connected to a pressure transducer with zero set at the level of the vulva. Sterile water was infused through the catheter at a rate of 5 mL/min; pressure was measured through a side port. The catheter was connected to a mechanical puller set to withdraw the catheter at a rate of 0.5 mm/s. The recording was marked for computer measurement of baseline urinary pressure within the bladder, maximal urethral pressure, end urethral pressure, and total profile length.⁹ **Maximal urethral closure pressure (MUCP)** was calculated by subtracting baseline urinary bladder pressure from maximal urethral pressure.

Dogs were taken outdoors after UPP measurements, and their voiding behavior was observed. When dogs were returned to the urodynamic laboratory for LPP measure-

ments,^{6,9} a 6-F, dual-lumen catheter^c was placed into the bladder and residual urine volume was measured while emptying the bladder. Anesthesia was induced by bolus administration of propofol (8 mg/kg, IV) and maintained by infusion of propofol at a rate of 0.4 mg/kg/min. The propofol infusion rate was adjusted as necessary to maintain a surgical plane of anesthesia, determined on the basis of central eye positioning, intact palpebral reflexes, absence of hind limb flexor reflex, and jaw tone. The trachea was intubated to provide supplemental oxygen, and the dog was positioned in dorsal recumbency. A large indirect blood pressure cuff as used for an adult human was placed loosely around the middle region of the abdomen, cranial to the level of the urinary bladder. The blood pressure cuff was not fastened or inflated until the transducers measuring LPP via a catheter were balanced and baseline bladder pressures were recorded. The bladder was infused with 75 mL of sterile water at a rate of 50 mL/min. The abdominal pressure cuff was inflated to 80 mm Hg, and additional abdominal pressure was applied by pressing 2 hands, 1 placed on top of the other, on the cuff until leakage of urine from the vulva was evident. The bladder pressure recorded at the time of leakage was defined as LPP (alternatively bladder LPP). This procedure was repeated so that at least 3 LPP measurements were made. An additional 25 mL of water was then infused into the bladder, and at least 3 more LPP tests were performed at a bladder volume of 100 mL. An additional 50 mL of water was then infused, and at least 3 more LPP tests were recorded at a bladder volume of 150 mL. The bladder was evacuated, and the dog was permitted to recover from anesthesia. For each bladder volume, a mean LPP was calculated.

Statistical analyses—Repeatability of LPP results for the bladder volumes (75, 100, and 150) at each evaluation and repeatability for mean LPP and the MUCP at each evaluation (for example at 2, 4, and 6 weeks after surgery) were compared by use of 1-way repeated-measures ANOVA. When results of normality tests identified a parametric distribution, data were compared by use of a Friedman repeated-measures ANOVA on ranks. Because there were no differences, mean LPP for the 3 bladder volumes and MUCP for the 3 evaluations were then calculated to yield a single LPP (LPP_{mean}) and a single MUCP (MUCP_{mean}) for each dog before and after each neurectomy. The urodynamic measurements (LPP_{mean} and MUCP_{mean}) as performed before and after each neurectomy were described as mean, median, SD, and interquartile range. Within each group, the urodynamic measurements (LPP_{mean} and MUCP_{mean}) before surgery, after the first surgery, and after the second surgery were compared by use of repeated-measures ANOVA. When results of normality tests identified a nonparametric distribution, the data were analyzed by use of the Friedman repeated-measures ANOVA. Urodynamic data (LPP_{mean} and MUCP_{mean}) from all 19 dogs were combined, and paired *t* tests were used to compare results obtained before the first surgery with those obtained after the second surgery. To determine whether differences existed between the 2 groups before surgery, urodynamic measurements (LPP_{mean} and MUCP_{mean}) and body weight recorded before and after both surgeries were compared by use of *t* tests. For all analyses, values of *P* < 0.05 were considered significant.

Results

All dogs remained healthy throughout the study period as determined by results of physical examinations, CBC, serum biochemical analyses, and urinalyses. A urinary tract infection, as defined by having pyuria (> 5 WBCs/hpf), bacteruria, or positive results on microbial culture of urine obtained via centesis, was

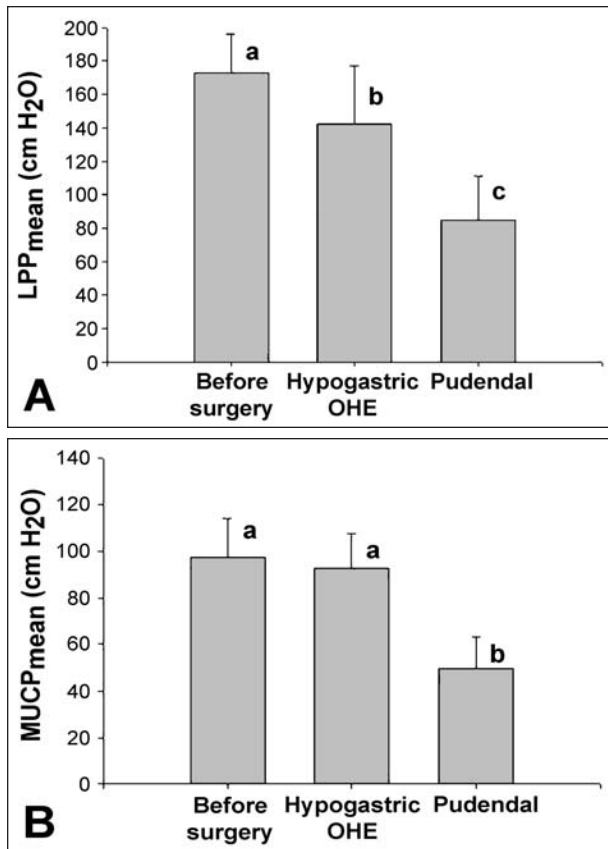


Figure 1—Mean \pm SD leak point pressure (LPP, panel A) and maximal urethral closure pressure (MUCP, panel B) in 10 dogs before surgery, after bilateral neurectomy of the hypogastric nerves and ovariohysterectomy (OHE), and after bilateral neurectomy of the pudendal nerves. ^{a,b}Values with different letters are significantly ($P < 0.05$) different.

not detected in any dog. All dogs voided normally before surgery. Fifteen dogs developed a degree of incontinence after selective neurectomy. Throughout the study, all dogs continued to posture and void a full stream of urine. Four dogs (1 dog in group 1 and 3 dogs in group 2) urinated normally throughout the study, 4 dogs (2 in group 1 and 2 in group 2) continued voiding when rising from their urination posture, 6 dogs (4 in group 1 and 2 in group 2) dribbled urine when walking away after urination, and 5 dogs (3 in group 1 and 2 in group 2) dribbled urine when active, especially when trotting. In each of the 4 dogs that urinated normally, values of $MUCP_{mean}$ and LPP_{mean} decreased after the second neurectomy; LPP_{mean} and $MUCP_{mean}$ before surgery were 189 and 126, respectively, whereas LPP_{mean} and $MUCP_{mean}$ after the second surgery were 104 and 66.5, respectively. All dogs appeared to have a normal ability to store and void urine as determined by observation and residual volume. Fecal incontinence or decreased external anal sphincter tone was not detected in any dog.

Before surgery, the mean values of LPP_{mean} and $MUCP_{mean}$ in all dogs were 169.3 ± 24.9 cm H₂O (mean \pm SD) and 108.3 ± 19.3 cm H₂O, respectively; these values decreased to 92.3 ± 27 cm H₂O and 60.7 ± 20.0 cm H₂O, respectively, after the second surgery. For group 1 dogs, which underwent hypogastric sym-

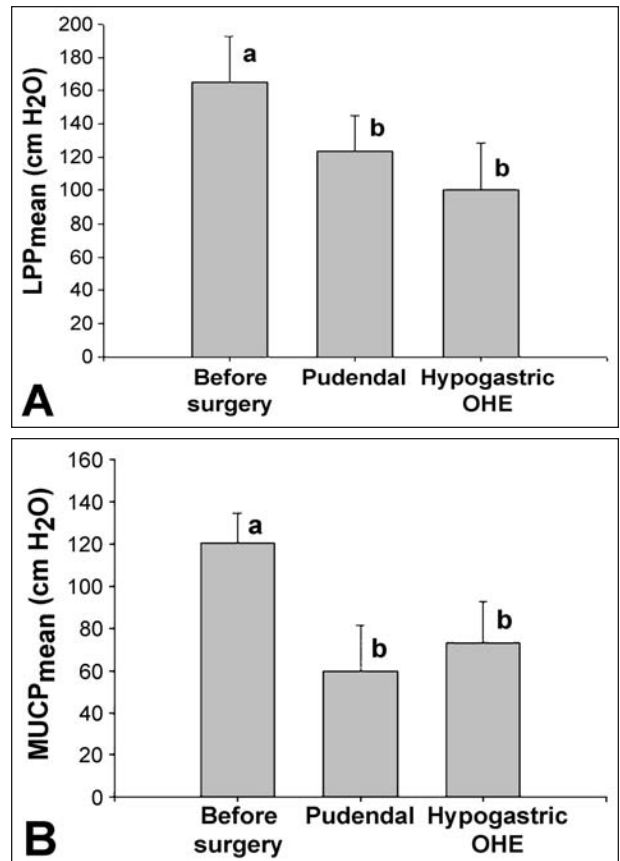


Figure 2—Mean \pm SD LPP (A) and MUCP (B) in 9 dogs before surgery, after bilateral neurectomy of the pudendal nerves, and after bilateral neurectomy of the hypogastric nerves and OHE. ^{a,b}Values with different letters are significantly ($P < 0.05$) different.

pathetic neurectomy and ovariohysterectomy first, there was a progressive and significant decrease of LPP from 173.1 ± 22.8 before surgery to 142.6 ± 34.8 after the first surgery and to 85.1 ± 26.4 after the second surgery (Figure 1). In contrast, there was no change in MUCP for group 1 after hypogastric neurectomy (92.5 ± 15.0 cm H₂O), compared with MUCP before surgery (97.3 ± 16.8 cm H₂O); however, MUCP decreased after pudendal neurectomy (49.9 ± 13.2 cm H₂O). For group 2 dogs, which underwent pudendal neurectomy first, there appeared to be a progressive decrease of LPP from 165.0 ± 27.8 before surgery to 123.2 ± 21.4 after pudendal neurectomy and to 100.3 ± 28.0 after hypogastric neurectomy and ovariohysterectomy; however, a significant difference was detected between LPP values only before and after pudendal neurectomy (Figure 2). The MUCP decreased from 120.4 ± 14.3 before surgery to 59.7 ± 21.7 after pudendal neurectomy and remained unchanged after hypogastric neurectomy and ovariohysterectomy.

Comparisons of the 2 groups of dogs identified a significant difference in body weights at the beginning of the study; dogs in group 1 weighed 26.3 ± 1.79 , and dogs in group 2 weighed 24.2 ± 1.5 . There were no significant differences in LPP_{mean} and $MUCP_{mean}$ before surgery between the 2 groups. There was no significant difference in LPP_{mean} after both surgeries between the

2 groups. Group 1 dogs had a significantly lower MUCP_{mean} (49.9 ± 13.2) after both surgeries than group 2 dogs (72.8 ± 20.0).

Discussion

In our study, selective neurectomy and ovariohysterectomy decreased LPP and MUCP in dogs. With the crossover design, the decrease in LPP was cumulative when either sympathetic or somatic nerves supplying the urethra were initially severed. Denervation of both sympathetic and somatic nerves was required to maximally decrease LPP. In contrast, MUCP appeared to decrease only when the pudendal nerves were severed, implying that most of this urodynamic measurement was caused by a loss of tone in the skeletal muscles of the external urethral sphincter. Striated muscles, of which the external urethral sphincter is composed, are essentially confined to the distal half of the urethra in dogs, with the strongest development of striated muscles in the distal quarter.¹¹ Although the most predominant constituents of the female dog's urethra are collagenous and elastic fibers, smooth muscle is spread uniformly throughout the length of the urethra.¹¹ Results of neurophysiologic studies have identified the somatic innervation of the external urethral sphincter as being the urethral branch of the pudendal nerve⁷ and the hypogastric nerve as the sole sympathetic supply to the pelvic plexus in dogs.⁸ The hypogastric nerves also innervate the urinary bladder,⁸ but there were no identifiable deficits in the function of the bladder to store and void urine after hypogastric denervation. A possible role for sympathetic innervation of the smooth muscles used in producing the MUCP measurements was identified by Augsberger et al,¹¹ who detected a positive correlation between the zone of the urethra and the greatest amount of smooth muscle and MUCP. In women undergoing radical hysterectomy, those with bilateral sympathectomies had an increased incidence of urinary incontinence, compared with those with complete preservation of the sympathetic nerves originating from the hypogastric nerve.¹²

In the study reported here, decrements of the clinical signs of urinary control were relatively modest in neurectomized dogs, in contrast to the large decreases in LPP and MUCP. The clinical signs in 15 of 19 dogs were distinctly abnormal but were so mild that it may be difficult to use clinical signs alone for evaluation of treatments in dogs undergoing selective neurectomy. Only 4 dogs urinated normally during all observation periods. The LPP_{mean} and MUCP_{mean} of those 4 dogs were higher before and after surgery, compared with the LPP_{mean} and MUCP_{mean} of all dogs. Those 4 dogs may have been incontinent, but the incontinence was not observed or the pudendal neurectomy may not have been complete, compared with the other dogs. Clinical signs of urinary incontinence were evaluated only when dogs were awake and active, not relaxed. Evaluation of urinary incontinence in research dogs at rest or asleep is assumed to be more difficult than evaluation of pets by owners. An owner is likely to be aware of the fact that their dog leaks when sleeping at home. Frequency and clinical signs of naturally developing urinary incontinence in spayed female dogs have been well described.

Clinical signs of urinary incontinence usually develop within 3 years of ovariohysterectomy.^{3,13} Sexually intact dogs are rarely reported as being incontinent, unless specific diseases can be identified as the cause. The classic sign of urinary incontinence in spayed female dogs is urine leaking during recumbency, particularly when asleep.^{3,13} An association between spaying and urinary incontinence while recumbent has been reported in various survey studies as 4.3%,² 9.7%,¹³ and 20.1%.³

When urodynamic tests are evaluated in spayed female dogs with naturally developing urinary incontinence, both the LPP and UPP tests generate below normal results, compared with clinically normal dogs.⁶ No significant differences were detected by use of a *t* test between urethral pressures (LPP_{mean} and MUCP_{mean}) of female dogs with naturally developing urinary incontinence⁶ and dogs after selective neurectomy in the study reported here. By use of a *t* test, the mean LPP (mean ± SD, 93.6 ± 34.3 cm H₂O) and MUCP (74.7 ± 32.1) of female dogs with naturally developing urinary incontinence⁶ were less than results of a previous study,⁹ in which LPP was 172.4 ± 24.6 and MUCP was 110.1 ± 20.2 for 22 clinically normal dogs. Holt^{4,5} has also reported low MUCP values for spayed dogs with naturally occurring urinary incontinence, compared with dogs with normal urinary control. The LPP in dogs with urinary incontinence responding successfully to colposuspension increases toward the reference range; however, MUCP does not increase.⁶ Successful treatment of spayed female dogs with naturally developing incontinence with phenylpropanolamine increases MUCP in dogs, probably because of the α -agonist effect on the sympathetically innervated smooth muscle.¹⁴ Abnormally caudal (distal) positions of the neck of the urinary bladder¹⁵ and the urethral meatus into the vestibule⁶ have been correlated with urinary incontinence in spayed female dogs. The neck of the urinary bladder of incontinent dogs is more mobile and moves more caudally when anesthetized dogs are positioned in right or left lateral recumbency,¹⁶ compared with dogs with normal urinary control. Cranial movement of the bladder neck and urethral meatus in relation to the pelvic cavity as a result of colposuspension has improved urinary control for incontinent spayed female dogs.¹⁷

In the study reported here, we assessed how well the selective neurectomy model would simulate stress incontinence in postmenopausal women and urinary incontinence seen in spayed female dogs. Urodynamic test results and urine leakage during activity of the dogs in this study were similar to those reported for women.^{1,18,19} Leak point pressure has become accepted as the urethral function test most predictive of the clinical signs of incontinence and response to treatment.^{1,20} Another similarity between incontinent postmenopausal women and spayed female dogs is a decrease in estrogen concentrations, compared with estrogen concentrations before aging or ovariohysterectomy.¹⁹ Bladder storage problems have been identified in both incontinent women²¹ and female dogs²² as being a contributing factor for urinary incontinence. Although cystometrograms and residual volumes did not identify storage problems in this model, sympa-

tectomy may have altered the balance between the bladder innervation by β -adrenergic and cholinergic nerves. Although not an area of frequent comparison, there are anatomic differences between women and female dogs. Dogs are quadrupeds, which may cause different pressure zones within the abdomen. The urethra is long in dogs (approx 10 cm in a 20-kg dog⁶) and, in the authors' experience, has a thin wall. In dogs, the urinary bladder and urethra are mobile, compared with their rigid mooring in women. The external urethral sphincter appears to extend longer and is more developed in women¹⁸ than in female dogs.¹¹ Anatomic differences are the major disadvantage of this neurectomy model in dogs for type III incontinence in women.

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- a. Janus System III (MC394) urodynamic system, Life-Tech Inc, Houston, Tex.
 - b. Urethral pressure profile catheter (UPP-8D), Life-Tech Inc, Houston, Tex.
 - c. Dual lumen catheter (DLC-6D), Life-Tech Inc, Houston, Tex.
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