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Urethral function after cystectomy: a canine in vivo experiment

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Summary. To study the function of the pelvic floor and the isolated urethra after removal of the bladder, 5 male and 5 female mongrel dogs were used in an acute in vivo experiment. Urethral pressure changes secondary to unilateral stimulation of the pelvic and pudendal nerves were recorded. After baseline data of the intact system were documented, the following procedures were carried out: separation of the urethra from the bladder neck (prostate), nerve-sparing cystectomy (cystoprostatectomy), and cold-knife incision through the entire length of the proximal urethra. Pressure recordings were repeated after each step of surgery. Pudendal nerve stimulation resulted in rapid and large pressure rises in the distal urethra (reaction typical of striated muscle). This response remained unchanged after all three surgical steps. Pelvic nerve stimulation provoked pressure rises within the urethra of a pattern typical of smooth muscle. The findings persisted after separation of the urethra from the bladder neck (prostate) and after cystectomy, but were not observed after urethrotomy. Contractions secondary to pudendal nerve stimulation were inhibited by curare, which did not affect the reaction to pelvic nerve stimulation. Our experiments demonstrate that in the dog the continuity of bladder and urethra is not required for the function of urethral closure mechanisms. The contractile potency of the urethral smooth muscles remains intact after nerve-sparing cystectomy. We believe that problems with the baseline continence of surrogate bladders should mainly be ascribed to a lack of surgical caution in preserving the autonomic nerves of cystectomy. A poor response to stress conditions cannot be explained by damage to the neural pathway of the striated sphincter, as the pudendal nerve is not at risk during nerve-sparing cystectomy. In our opinion mechanical malfunction of the striated muscle components secondary to scarring at the site of the anastomosis is the main reason for stress incontinence after orthotopic bladder replacement.

Key words: Bladder replacement – Cystectomy – Isolated urethra – Nerve stimulation

In the era of functional blader replacement, increasing interest is focused upon urethral function after cystectomy. We have analyzed the striated and smooth sphincteric components after nerve-sparing radical cystectomy in male and female dogs to elucidate possible reasons for unsatisfactory results after functional replacement of the bladder [9, 10].

Materials and methods

To study the function of the pelvic floor and the isolated urethra after removal of the bladder, 5 male and 5 female mongrel dogs weighing 20–25 kg (mean 22.5 kg) were used in an acute in vivo experiment. The dogs were premedicated with intramuscular acepromazine (1 mg/kg body weight) and anesthetized with intravenous sodium pentobarbital (25 mg/kg body weight). An endotracheal tube was placed to facilitate free ventilation. An angiocatheter was inserted into the femoral vein for saline infusion (5–10 ml/kg body weight per hour) and bolus injection of pentobarbital throughout the experiment. To prevent hypothermia, a water-circulating blanket (Gaymar, Orchard Park, NY) was positioned under the dog to keep the rectal temperature above 37.8 °C during the experiment.

Cuff electrodes developed in our lab were placed around the pudendal and pelvic nerves and secured with two 4-0 Dermalon sutures. A 7-French membrane catheter was then introduced into the urethra and connected to a Statham p23 transducer (Hato Rey, Puerto Rico). Pressures were read on a Grass model 7 polygraph (Grass Instruments, Quincy, Mass). Pressure changes secondary to unilateral stimulation of the pelvic nerve (10 mA, 20 Hz) were recorded with the membrane catheter in the proximal urethra; those secondary to stimulation of the pudendal nerve (3 mA, 20 Hz) were recorded with the membrane catheter in the distal urethra. The position of the balloon in the urethra was checked by rectal examination.

After the baseline data of the intact system had been determined, the following procedures were carried out: separation of the continuity between urethra and bladder neck (prostate), nerve-

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Table 1. Urethral pressure changes in response to pelvic or pudendal nerve stimulation under varying conditions

	Pre-cystectomy		Post-cystectomy		Curare		Urethrotomy	
	Pelvic	Pudendal	Pelvic	Pudendal	Pelvic	Pudendal	Pelvic	Pudendal
Male dogs								
1	35	>100	35	>100	35	0	0	0
2	25	>100	25	>100			0	>100
3	35	95	25	95	35	0	0	0
4	30	80	25	80			0	80
5	30	>100	30	>100			0	>100
Female dogs								
6	30	85	30	85	30	0	0	0
7	35	75	30	75			0	70
8	25	>100	20	>100	20	0	0	0
9	20	70	10	65			0	65
10	30	>100	25	>100			0	>100

All values are in cm H_2O

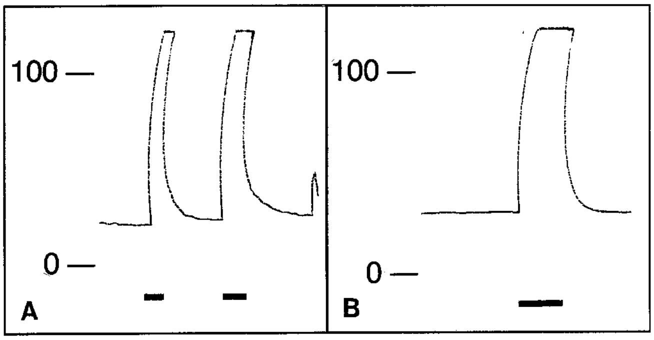


Fig. 1A, B. Intraurethral pressure rise (cm H_2O) secondary to pudendal nerve stimulation **A** repeated stimulations; **B** after cystectomy and urethrotomy

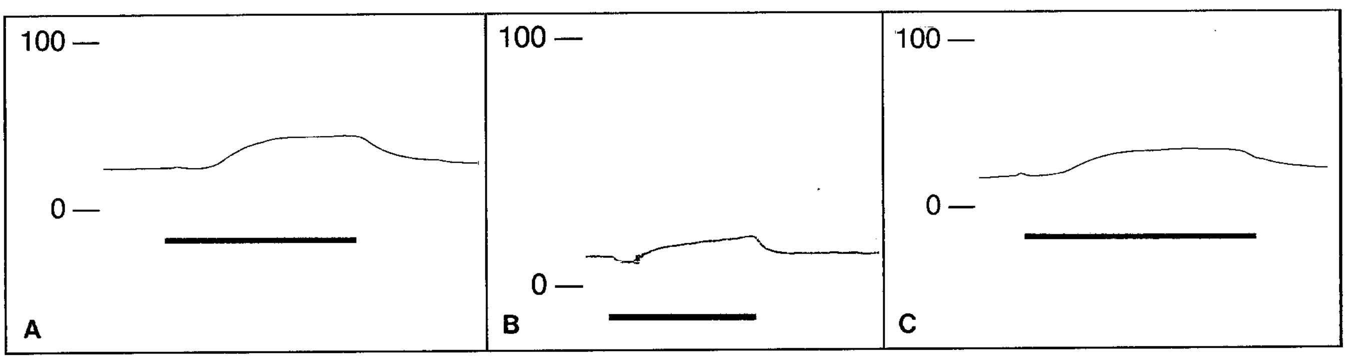
sparing cystectomy (female dogs) or cystoprostatectomy (male dogs), and cold-knife incision through the entire length of the proximal urethra. At cystectomy/cystoprostatectomy the fibers leading to the bladder were divided, but the pelvic nerve itself and particularly the fibers travelling caudad to supply the urethra were preserved. Neural stimulation and pressure recordings were repeated after each step of surgery. Four animals received curare (0.8 mg/kg body weight) before an additional stimulation of pelvic and pudendal nerves prior to urethrotomy.

Results

All pressure changes recorded after unilateral stimulation of the pelvic and pudendal nerves are listed in Table 1. Pudendal nerve stimulation resulted in rapid and large pressure rises in the distal urethra (characteristic of a striated muscle reaction). Repetition of the stimulation within short intervals resulted in a consistent response (Fig. 1A). This remained unchanged after urethral separation from the bladder neck (prostate), cystectomy, and urethrotomy (Fig. 1B). In two animals (7, 9) the pressures recorded at the end of the experiment were lower than at the beginning, most likely secodary to weakness owing to the length of the experiment and blood loss.

Pelvic nerve stimulation provoked pressure rises within the urethra of a typical smooth muscle pattern (Fig. 2A). There was a significant delay of 0.8–1.5 s between the onset of stimulation and the reaction, in some cases there was even an initial pressure decrease (Fig. 2B). The findings persisted after separation of the urethra from the bladder neck (prostate) and after cystectomy (Fig. 2C);

Fig. 2A, C. Intraurethral pressure rise (cm H_2O) secondary to pelvic nerve stimulation **A, B** intact system; **C** after cystectomy



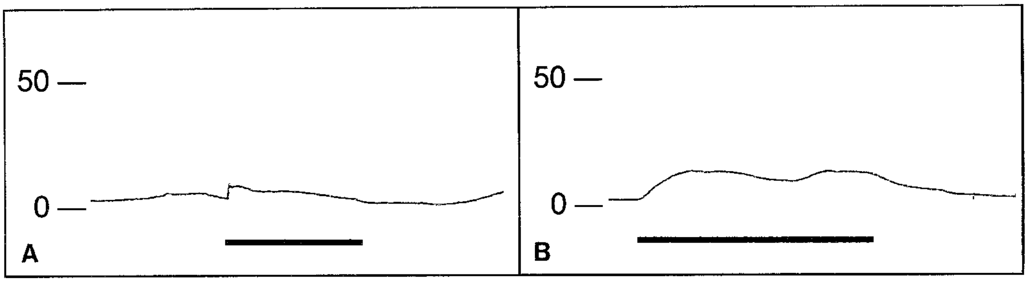


Fig. 3A, B. Intraurethral pressure changes (cm H_2O) secondary to neural stimulation after administration of curare: **A** pudendal nerve stimulation; **B** pelvic nerve stimulation

however, as could be expected, the contractions were no longer observed after urethrotomy. The comparatively weaker response to pelvic nerve stimulation after cystectomy in some animals (mainly 9) was probably caused by less careful dissection.

The contractions secondary to pudendal nerve stimulation were completely inhibited by curare; the reaction to pelvic nerve stimulation remained unchanged (Fig. 3A, B).

Discussion

The functions of the separated urethra are of particular interest for surrogate bladders. As is the case under physiological conditions, there are two components of continence after bladder replacement: baseline and stress continence. Insufficient baseline continence may arise secondary to a low urethral tonus after surgery. This scenario would result in permanent leakage during moderate pressure rises within the pouch. Stress continence is provided by abdominoperineal pressure transmission and the reaction of the striated sphincter and pelvic floor secondary to acute intra-abdominal pressure rises (coughing, sneezing, etc.).

Using the dog as animal model for continence mechanisms is questionable. The construction of the pelvic floor is entirely different from that in the human, and the bladder is located higher in the abdomen. The proximal urethra in both male and female dogs is comparatively long and thick-walled. Although this facilitates exact pressure recording, it represents a significant difference from human anatomy [11]. Urethral closure mechanisms, even in female dogs, resist intravesical pressures of up to 100 cm H_2O and still provide continence [3]. However, our model permits differentiation of the striated and smooth muscle components before and after cystectomy. Stimulation of the pelvic nerve provokes smooth muscle contractions of the urethra. The outer circular muscle layer appears to be responsible for urethral pressure rises secondary to pelvic nerve stimulation; the innner longitudinal coat has been reported to help minimize urethral resistance during voiding. This mechanism may be responsible for the initial pressure decrease immediately after pelvic nerve simulation [9]. Pudendal nerve stimulation results in contractions of the striated sphincter components [8]. After administration of curare no pressure changes whatsoever were observed secondary to pudendal nerve stimulation [10].

Baseline continence is provided by the so-called mucosal sphincter, bladder neck and urethra, elastic fibers of the urethral wall, submucosal vascular plane, and the resting tone of the striated muscles within the pelvic floor. Clinical experience teaches that baseline continence can be achieved by surgical techniques that spare the neurovascular bundle at cystectomy [13, 14]. The preservation of the autonomic nerve fibers is of particular importance. Our experiments demonstrate that the continuity of bladder and urethra is not necessarily required for the function of urethral closure mechanisms. The contractile potency of the urethral smooth muscles, which are capable of the long-term tonic contraction necessary for baseline continence, remains intact after nerve-sparing cystectomy. In patients given a low-pressure pouch with sufficient capacity, problems with baseline continence can be mainly ascribed to a lack of caution in preserving the autonomic nerves at cystectomy. Cold-knife incision of all urethral layers terminated the smooth muscle response secondary to pelvic nerve stimulation. However, the function of this component may partly be taken over by the striated extrinsic sphincteric system in certain clinical situations [6].

Stress continence is provided by pressure transmission to the urethra and the intact striated muscle components of the extrinsic closure mechanisms [1, 2, 4, 7, 12]. It has previously been shown that the reflex response of pelvic floor contractions secondary to stress conditions precedes the intra-abdominal pressure rise in these conditions. Thüroff demonstrated that the active reflex contraction of the external sphincter and the pelvic floor muscles secondary to sneezing exceeded the passive increase in bladder pressure [10, 12]. Continuity between bladder and urethra was not a prerequisite for this function [12]. As the pudendal nerve is normally not at risk during cystectomy, the poor response to stress conditions cannot be explained by damage to the neural pathway for this reflex. A mechnical malfunction of the striated muscle components secondary to scarring is therefore considered the main reason for stress incontinence after bladder replacement. We believe that the techniques of pelvic floor dissection and suturing of the anastomosis are the factors responsible for a sufficient pelvic floor response to stress conditions.

Our data point out the importance of both nerve-sparing cystectomy and a delicate technique of urethral anastomosis for satisfactory continence after functional bladder replacement. In the dog, essentially no differences were found between the data gained from male and female animals. This may be of importance for the principal understanding of future models for female bladder replacement [5]; however, the difference from human anatomy must be borne in mind.

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