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Evaluation of pudendal nerve regeneration following neurotmesis in a rabbit model

R.Kh. Al-Jubouri and H.A. Al-Timmemi

Departments of Surgery and Obstetrics, College of Veterinary Medicine, University of Baghdad, Baghdad, Iraq

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Correspondence:
R.Kh. Al-Jubouri
rania.khedr2202m@covm.uobaghdad.edu.iq

Abstract

The pudendal nerve (PDN) plays a crucial role in external urethral sphincter (EUS) innervation, contributing to urinary control and coordinating the action of bladder with the external urethral sphincter. This study aimed to evaluate the impact of pudendal nerve neurotmesis, with and without subsequent end-to-end coaptation on external urethral sphincter function and coordination with bladder. Twenty healthy female New Zealand White rabbits were randomly divided into two groups. In the control group, pudendal nerve neurotmesis was performed without any subsequent intervention. In the treated group, pudendal nerve neurotmesis was followed by end-to-end nerve coaptation. Clinical evaluation was assessed weekly post-operative (PO) through bladder dairy calculation once per week for a duration of 24 hours, that include: incontinence episodes, daily fluid intake, volume of each void, and periods between each void, to monitor urination patterns and behavioral changes. Cystometry test was performed in 4th and 16th weeks PO that included the following parameters: detrusor pressure (P det), bladder capacity (BC), bladder compliance (BCom), leak point pressure (LPP), and frequency (number of leaks) to measure bladder dynamics and physiological responses. The results revealed high significant differences ($P \leq 0.05$) between control and treated groups, including alterations in bladder dairy evaluations and in cystometry parameters. The findings support that end-to-end pudendal nerve coaptation facilitates functional nerve regeneration and contributes to the restoration of EUS control.

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Introduction

The peripheral nervous system (PNS) represents a highly heterogeneous entity with a broad range of functions, ranging from providing communication between the brain and the body to controlling development (1). Peripheral nerve injury (PNI) is a medical problem mainly caused by external trauma after stretching, tearing, or extrusion of peripheral nerves (2). Stress urinary incontinence (SUI), is one of lumbosacral lesions (3) caused by injures of spinal cord, or pudendal nerve that innervate the area of the bladder and urethra (4). After transection injury to pudendal nerve, the (SUI) is the most common disorder (5). Stress urinary incontinence, is defined as involuntary loss of urine during the filling phase of the bladder, occurs due to failure of voluntary control of the external urethral sphincter (6), it is a commonly seen problem in veterinary practice (7). Surgical treatment for the transected pudendal nerve: End-to-end tension-free coaptation has traditionally been the preferred repair method in lesions with a gap smaller than 5 mm (8). Primary end-to-end neurorrhaphy (ETE) is the current standard for nerve repair if the repair can be performed in a tension-free manner (9). Various end-to-end repair techniques have been developed, including epineural, fascicular, and group-fascicular repair (10). Epineurial repair involves placing microsutures through the epineurium without damaging the fascicles. This technique minimizes the amount of suture material between the nerve ends,

thereby promoting axonal regeneration. Additionally, it is technically less complex and avoids axonal damage (11).

Materials and methods

Ethical approval

All experimental animals were used in this study approved by the Scientific Committee of the College of Veterinary Medicine, University of Baghdad in compliance with the ethical principles' guidelines on the care and use of animals in research (approval no: 5871 P.G, date 13/3/2024) of animal welfare.

Experimental Design

This study utilized twenty healthy adult female New Zealand white rabbits weighed 1.3-1.9 kg, and aged 6 months -12 month as experimental subjects. All experimental animals were individually housed in cages and provided with commercial food and an adequate amount of water.

A 15-day acclimatization period was given to allow the rabbits to adjust to their new environment. During this period, the rabbits received a daily intramuscular administration of ceftriaxone, a broad-spectrum antibiotic (Gulf Pharmaceutical Industries, Ras Al Khaimah, U.A.E.), for five consecutive days at a dosage of 20 mg/kg. Additionally, on the first day and day 14, they were given a subcutaneous injection of Ivermectin, an anthelminthic (Facmed Pharmaceuticals Private Limited, Matiala, New Delhi), at a dosage of 0.2 mg/kg (12). Under general anesthesia, the neurotmesis of the left motor branch of pudendal nerve (MBPDN) created stress urinary incontinence. Based on the treatment method, the animals were then divided randomly into two equal groups: control group and treated group; Control group: The neurotmesis was left untreated, and treated group: The neurotmesis was repaired using end-to-end coaptation.

Anesthetic Protocol

Prior to the surgical procedure, food was withheld from the rabbits for a duration of two hours. Acepromazine maleate (Holland, Neurotranq, Alfasan™) was injected intramuscularly (IM) as pre-anesthetic drug at a dose of 1 mg/kg body weight, followed by injection of a mixture of 50 mg/kg of Ketamine hydrochloride (Holland, 10% Ketamine, Alfasan™), 4 mg/kg of Xylazine hydrochloride (Holland, 2% Xylazine, Alfasan™) IM (13).

Surgical Protocol

The prepare positioned of female rabbit in ventral recumbency, and the surgical aperture was crafted on the dorsal midline just above the area from acetabulum and downward under tuber ischi through fenestrated surgical drape at the designated surgical site. Skin incision was made, 1 cm left lateral to dorsal midline and extending from the greater trochanter downward to the tuber ischi. Both the subcutaneous layer and facia were sectioned, thus sectioning the gluteus maximus muscle and the muscle underneath it, the gluteus medius muscle. Muscle section was achieved using the blunt dissection approach, facilitated by mayo scissors, revealing the underlying neurovascular structures including the pudendal artery and vein lateral to vertebral column, and the motor branch of pudendal nerve (MBPDN) medial to vertebral column. In the control group, the MBPDN was laid bare at the operation site using self-retaining wound dilator, and neurotmesis was executed using micro surgical scissors to cut the nerve from mid-portion (Figure 1). For end-to-end coaptation of the nerve, after neurotmesis of MBPDN, Coaptation of proximal and distal segments of the nerve was done by two interrupted epineurial sutures using 8-0 nylon sutures (Figure 1) the coaptated nerve reposition carefully flushed with physiological saline and the excessive saline was swabbed with sterile gauze.

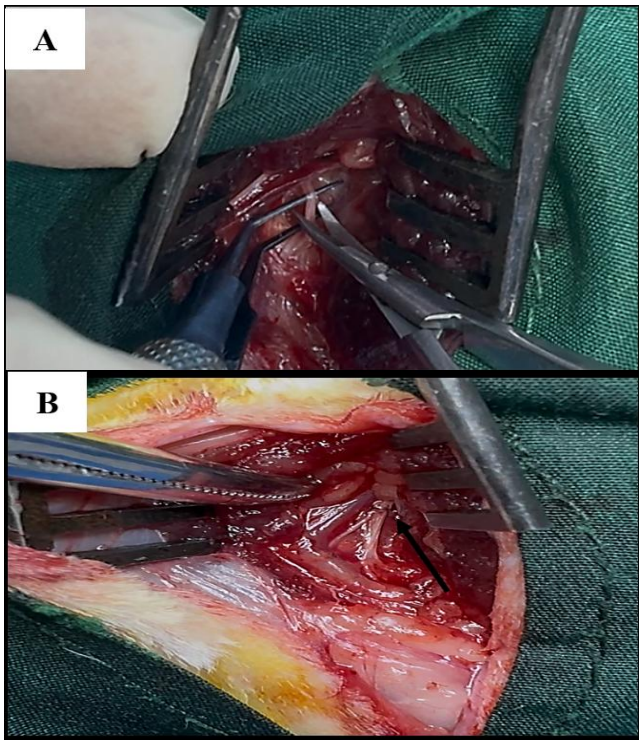

Figure 1: Surgical procedure for pudendal nerve neurotmesis and repair. A. Neurotmesis of the motor branch of pudendal nerve was performed using micro surgical scissors. B. End-to-end coaptation of transected motor branch of pudendal nerve (arrow).

Clinical Evaluation

The motor signs of operated MBPDN were evaluated at 2nd, 4th, 8th, and 16th weeks post operative (once per week for a duration of 24 hours). The evaluation of all animals was performed to calculate the bladder dairy weekly, using the

parameters that included the incontinence episodes, daily fluid intake, volume of each void, and periods between each void (14). The motor abilities of the animals include their beginning of voluntary control of the urination.

Cystometry Test

Assessment of the function of bladder and urethra was performed in periods of 4th and 16th weeks PO, using parameters that included the detrusor pressure (P det), bladder capacity (BC), bladder compliance (BCom), leak point pressure (LPP) and the frequency (number of leaks) (14).

Statistical Analysis

The Statistical Packages of Social Sciences-SPSS (2019) program were used to detect the effect of different factors (treatment and period) in study parameters. LSD-Least significant difference was used to significantly compare among means in this study (15).

Results

Bladder Dairy Evaluations

Incontinence Episodes

At 2nd week PO, treated group (30.20 ± 0.80) had fewer incontinence episodes compared to control group (35.20 ± 0.58), with control group showing significantly ($P \leq 0.05$) higher number of episodes. At 4th week PO, treated group (28.80 ± 0.73) which was significantly lower ($P \leq 0.05$) than control group (40.00 ± 1.48). At 8th week PO, treated group (24.20 ± 1.02) showed a significant difference improvement ($P \leq 0.05$), compared to control group (51.60 ± 2.11) with the treated group showed much fewer episodes than the control group. At 16th week PO, the treated group (10.20 ± 0.58) showed a dramatic reduction in incontinence episodes compared to control group (88.60 ± 1.69), which was statistically significant ($P \leq 0.05$), with the treated group showed the most improvement, (Table 1).

Table 1: Comparison between control and treated groups in Incontinence Episodes

Week	Treated Group Mean ±Se	Control Group Mean ±Se
2nd Week	30.20 ±0.80 b	35.20 ±0.58 a
4th Week	28.80 ±0.73 b	40.00 ±1.48 a
8th Week	24.20 ±1.02 b	51.60 ±2.11 a
16th Week	10.20 ±0.58 b	88.60 ±1.69 a

* LSD = 3.62, $P \leq 0.05$.

Daily Fluid Intake

At 2nd week PO, the fluid intake in treated group (705.60 ± 14.23) was lower than in control group (769.80 ± 10.37), the difference in fluid intake between treated and control groups was statistically significant ($P \leq 0.05$). At 4th week PO, treated group (678.80 ± 11.32) showed a significantly ($P \leq 0.05$) lower fluid intake than control group (826.80 ± 20.35) indicating a clear difference in fluid consumption between both groups. At 8th week PO, treated group (626.40 ± 13.18) had fluid intake which was significantly ($P \leq 0.05$) lower compared to control group (902.20 ± 38.68) which showed the substantial gap in fluid intake between both groups at this point. At 16th week PO, treated group (374.80 ± 19.67) shows a marked decrease in fluid intake, as significantly ($P \leq 0.05$) lower compared to control group (1050.20 ± 41.87) as shown in (Table 2).

Table 2: Comparison between control and treated groups in Fluid Intake (ml)

Week	Treated Group Mean ±Se	Control Group Mean ±Se
2nd Week	705.60 ±14.23 b	769.80 ±10.37 a
4th Week	678.80 ±11.32 b	826.80 ±20.35 a
8th Week	626.40 ±13.18 b	902.20 ±38.68 a
16th Week	374.80 ±19.67 b	1050.20 ±41.87 a

* LSD = 63.718, $P \leq 0.05$.

Volume of Each Void

At 2nd week PO, treated group (23.40 ± 0.51) had a significantly higher mean volume when compared to control (18.40 ± 0.60), as statistical significance difference ($P \leq 0.05$). At 4th week PO, treated group (23.60 ± 0.40) again showed a significantly ($P \leq 0.05$) higher volume of each void compared to control group (17.40 ± 0.41). At 8th week PO, treated group (26.00 ± 0.77) exhibited a significantly ($P \leq 0.05$) higher void volume than control group (14.60 ± 0.75). At 16th week PO, treated group (36.80 ± 0.48) showed the significantly ($P \leq 0.05$) higher volume voided compared with control group (9.80 ± 0.37) which had the lowest volume voided, there by confirming the progressive positive effect end-to-end nerve coaptation over time, as shown in (Table 3).

Table 3: Comparison between control and treated groups in Volume of Each Void (ml)

Week	Treated Group Mean ±Se	Control Group Mean ±Se
2nd Week	23.40 ±0.51 a	18.40 ±0.60 b
4th Week	23.60 ±0.40 a	17.40 ±0.41 b
8th Week	26.00 ±0.77 a	14.60 ±0.75 b
16th Week	36.80 ±0.48 a	9.80 ±0.37 b

* LSD = 1.08, $P \leq 0.05$.

Periods Between Each Void

At 2nd week PO, treated group (47.80 ± 1.24) had a significantly as statistical significance difference ($P \leq 0.05$) longer periods compared to control group (40.80 ± 0.58). At 4th week PO, again treated group (50.00 ± 1.30) had a

significantly (P≤0.05) longer periods than control group (36.00 ± 1.48). At 8th week PO, treated group (60.20 ± 2.71) also had a significantly (P≤0.05) longer periods than control group (28.20 ± 1.28). At 16th week PO, treated group (143.00 ± 7.91) had a significantly (P≤0.05) longer periods compared to control group (16.40 ± 0.40) as shown in (Table 4), this positive outcome indicated that the animal can tolerate higher bladder volumes without triggering involuntary voiding which indicate functional pudendal nerve regeneration.

Table 4: Comparison between control and treated groups in Periods Between Each Void (minutes)

Week	Treated Group Mean ±Se	Control Group Mean ±Se
2nd Week	47.80 ±1.24 a	40.80 ±0.58 b
4th Week	50.00 ±1.30 a	36.00 ±1.48 b
8th Week	60.20 ±2.71 a	28.20 ±1.28 b
16th Week	143.00 ±7.91 a	16.40 ±0.40 b

* LSD = 6.27, P ≤ 0.05.

Cystometry Parameters

Detrusor Pressure (P det)

At 4th week PO, the mean (P det) was slightly higher in control group (21.40 ± 0.24 cmH_2O) when compared to treated group (20.40 ± 0.24 cmH_2O), as the significant difference (P ≤ 0.05). At 16th week PO, the difference between treated and control groups became more pronounced. The P det in control group (23.00 ± 0.31 cmH_2O) was significantly (P ≤ 0.05) higher than in treated group (18.40 ± 0.24 cmH_2O) as showing in (Table 5).

Table 5: Comparison between control and treated groups in P det (cmH2O) in 4 and 16 weeks

Week	Treated Group Mean ±Se	Control Group Mean ±Se	T-Test
4th Week	20.40 ± 0.24	21.40 ± 0.24	0.798 *
16th Week	18.40 ± 0.24	23.00 ± 0.31	0.922 *

* (P≤0.05).

Bladder Capacity (BC)

At 4th week PO, the mean BC in treated group (24.00 ± 0.45 ml) was significantly (P ≤ 0.05) higher than in control group (18.20 ± 0.37 ml). At 16th week PO, there was a much larger difference between the two groups, treated group had a significantly (P ≤ 0.05) higher BC (64.20 ± 1.65 ml) when compared to control group (7.00 ± 0.45 ml) as shown in (Table 6), indicating a strong treatment effect over time.

Bladder Compliance (BCom)

At 4th week PO, the BCom in treated group (1.12 ± 0.02 cmH_2O) was significantly (P ≤ 0.05) higher than in control group (0.890 ± 0.01 cmH_2O). At 16th week PO, there was a much larger difference between the two groups. Treated group had a significantly (P ≤ 0.05) higher BCom (2.78 ± 0.04 cmH_2O) when compared to control group (0.376 ± 0.02 cmH_2O) as shown in (Table 7), indicating that the treatment had a progressively stronger effect on BCom overtime.

Table 6: Comparison between control and treated groups in BC (ml) in 4 and 16 weeks

Week	Treated Group Mean ±Se	Control Group Mean ±Se	T-Test
4th Week	24.00 ±0.45	18.20 ±0.37	1.344 *
16th Week	64.20 ±1.65	7.00 ±0.45	3.954 *

* (P≤0.05).

Table 7: Comparison between control and treated groups in BCom (cmH2O) in 4 and 16 weeks

Week	Treated Group Mean ±Se	Control Group Mean ±Se	T-Test
4th Week	1.12 ±0.02	0.890 ±0.01	0.062 *
16th Week	3.79 ±0.15	0.376 ±0.02	0.350 *

* (P≤0.05).

Leak Point Pressure (LPP)

At 4th week PO, treated group had a LPP mean of (11.60 ±0.24 cmH_2O), control group had a LPP mean of (7.40 ±0.24 cmH_2O) indicating that the statistical analysis showed significant difference (P ≤ 0.05). At 16th week PO, treated group had a higher LPP mean of (16.00 ±0.44 cmH_2O), control group had significantly (P ≤ 0.05) much lower LPP mean of (3.80 ±0.20 cmH_2O) as shown in (Table 8). This indicated that the treatment led to improvement in LPP over time.

Table 8: Comparison between control and treated groups in LPP (cmH_2O) in 4 and 16 weeks

Week	Treated Group Mean ±Se	Control Group Mean ±Se	T-Test
4th Week	11.60 ±0.24	7.40 ±0.24	0.798 *
16th Week	28.00 ±0.45	18.80 ±0.49	1.529 *

* (P≤0.05).

Frequency (Leaks)

At 4th week PO, the mean urinary frequency in treated group (2.60 ± 0.24) was significantly (P ≤ 0.05) lower than control group (4.40 ± 0.24), as shown in (Table 9) and in (Figure 2 and 4). At 16th week PO, the difference between the two groups became even more pronounced. Treated group had a urinary frequency of (0.00 ± 0.00), while control had a significantly higher frequency (8.00 ± 0.45), as statistical significance (P ≤ 0.05) as shown in (Table 9) and in (Figure 3 and 5), indicating that the treatment had a strong long-term effect in eliminating urinary frequency.

Table 9: Comparison between control and treated groups in Frequency in 4 and 16 weeks

Week	Treated Group Mean ±Se	Control Group Mean ±Se	T-Test
4th Week	2.60 ±0.24	4.40 ±0.24	0.798 *
16th Week	0.00 ±0.00	8.00 ±0.45	1.031 *

* (P≤0.05).

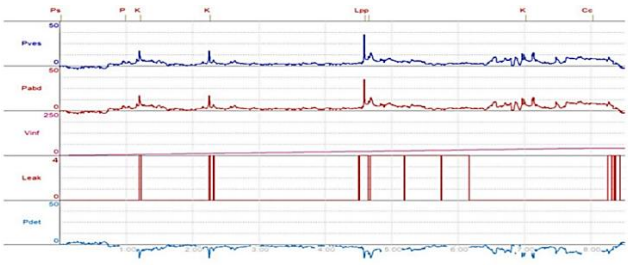

Figure 2. Cystometry examination in control group at 4th week post operative, the chart demonstrates 4 leakages with 6 episodes of increased intra-abdominal pressure (P abd) followed by increased intra-vesical pressure (P ves), continuous leakage at bladder capacity of 17 ml.

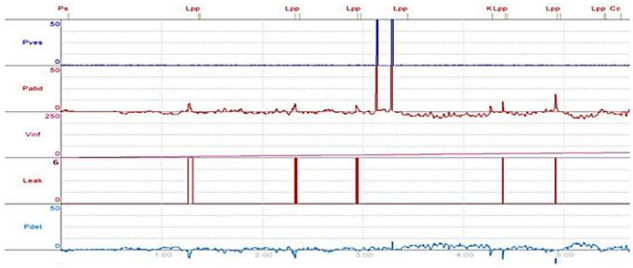

Figure 3: Cystometry examination in control group at 16th week post operative, the chart demonstrates 6 leakages with 6 episodes of increased intra-abdominal pressure (P abd) followed by increased intra-vesical pressure (P ves), continuous leakage at bladder capacity of 6 ml.

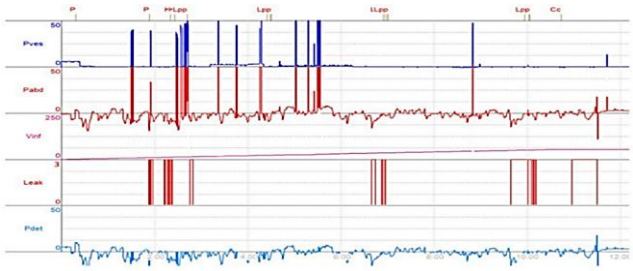

Figure 4: Cystometry examination in treated group at 4th week post operative, the chart demonstrates 3 leakages with 6 episodes of increased intra-abdominal pressure (P abd) followed by increased intra-bladder vesical (P ves), continuous leakage at bladder capacity of 25 ml.

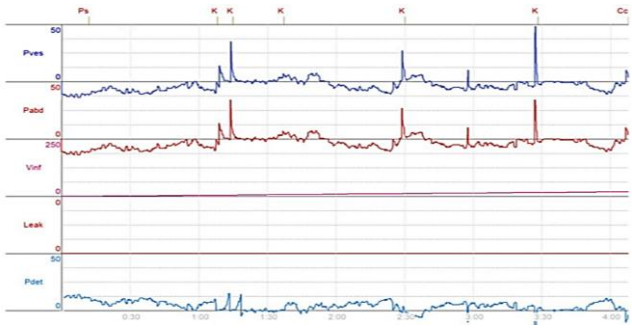

Figure 5: Cystometry examination in treated group at 16th week post operative, the chart demonstrates no leakage with each episode of increased intra-abdominal pressure (P abd) followed by increased intra-vesical pressure (P ves), continuous leakage at bladder capacity of 68 ml.

Discussion

Bladder Dairy Evaluations

Incontinence Episodes

At 2nd week PO, the higher number of episodes that occurred in control group is due initial functional impairment of external urethral sphincter in control group, this agrees with (16) who found that the neurotmesis of pudendal nerve can led to stress urinary incontinence due to denervation of external urethral sphincter. At 4th and 8th weeks PO, the treated group showed fewer incontinence episodes compared to control group, due to the improvement of pudendal nerve function in treated group, and this agree with (17) who indicated that the functional assessment of end-to-end coaptated pudendal nerve often show significant improvements in nerve conduction and associated urinary behaviors. At 16th week PO, the treated group showed a dramatic reduction in incontinence episodes compared to control group. The improvement of treated group agrees with (18) who found that reinnervation of external urethral sphincter leads to improved sphincteric function and better closure pressure, restoration of voluntary continence mechanism, and reduction of stress and urge incontinence episodes. A study indicated that pudendal nerve regeneration can decrease daily incontinence episodes with some patients achieving complete continence (19). While the control group getting worse due to chronic stress urinary incontinence triggers the release of pro-inflammatory cytokines, which can affect bladder function and lead to increase frequency (20). furthermore, decreased urethral resistance can lead to increase urgency and frequency of voiding as the bladder may not effectively retain urine (21). The injury of pudendal nerve promotes neurogenic detrusor overactivity, where the bladder begins to contract involuntarily during the filling phase and this result in decreased functional bladder capacity and early sensation of fullness. Detrusor overactivity develops due to disinhibition of parasympathetic bladder

reflexes, and this contribute to urge incontinence in addition to the existing sphincteric deficiency (22). Also, a study of pudendal nerve injury in rats exhibited increased urinary frequency constant with overactive bladder symptoms (23).

Daily Fluid Intake

At 2nd week PO, the higher volumes of fluid intake in control group compared to treaed group is due to compensatory polydipsia occurred in control group and this result consent with (24) who found that stress urinary incontinence can trigger polydipsic behavior, potentially leading to excessive fluid intake and subsequently diuresis. At 4th and 8th weeks PO, treated group showed lower volumes of fluid intake indicating a clear difference in fluid consumption between both groups especially at 8th week PO which showed the substantial gap in fluid intake between both groups at this point. Also, at 16th week PO, treated group showed a marked decrease in fluid intake compared to control group. The data revealed that the treated group's fluid intake progressively returning to the normal over the 16 weeks and this result agreed with (22) who found that after regeneration of pudendal nerve, the improvement in external urethral sphincter function leads to decrease compensatory fluid behaviors, reduction of thirst that related to overactivity-driven diuresis and psychological discomfort, and restoration of normal fluid balance behaviors.

Volume of Each Void

At 2nd week PO, control group showed lower mean volume of each void compared to treated group, due to lose of coordination between detrusor muscle and denervated external urethral sphincter which led to bladder over activity and this outcome concurred with a study of pudendal nerve injury in rats exhibited increased urinary frequency and reduced voiding volumes, this consent with overactive bladder symptoms (23). At 4th, 8th, and 16th weeks PO, the treated group showed higher mean volumes of each void compared to control group, so that positive effect of the treatment over time and this result agreed with (24) who found that following the regeneration of pudendal nerve there is restoration of bladder compliance and bladder capacity due to restoration of coordination between detrusor muscle and external urethral sphincter function leading to restoration of normal voiding pathways which allow larger and voluntary voids, also a studies found that pudendal nerve regeneration has been associated with increase bladder capacity and enhancing the ability to retain urine and reducing urgency (25, 26).

Periods Between Each Void

At 2nd, 4th, and 8th weeks days PO, the control group showed lower peroids between each void compared to treated group, due to weakness of external urethral sphincter as demonstrated by (27) who concluded that the external urethral sphincter relies on proper pudendal nerve function for effective contraction, also this result constant with studies of (26,28) who found that pudendal nerve injury leads to decreased urethral resistance and affecting voiding patterns. At 16th week PO, the treated group showed longer peroids between each void, this positive outcome indicating that the treated group can tolerate higher bladder volumes without triggering involuntary voiding which indicate functional pudendal nerve regeneration, this result agreed with (29) who indicated that following the regeneration of pudendal nerve, the recovery of bladder storage function and restoration of ability to delay voiding due to improved afferent signaling and sphincteric control.

Cystometry Parameters

Detrusor Pressure (P det)

At 4th week PO, the mean (P det) was slightly higher in control group compared to treated group, because the neurotmesis lead to detrusor overactivity that occurred in control group and this corresponded with (30) who approved that pudendal nerve facilitates the vesico-inhibitory reflex which helps inhibit detrusor contractions during bladder filling by stimulating contraction of external urethral sphincter, also the injury to the pudendal nerve distrust the neural pathways that coordinate bladder and external urethral sphincter function leading to detrusor overactivity (31). At 16th week PO, the difference between treated and control groups became more pronounced. The P det in control group was higher than in treated group, this presented that the effect of the treatment became more substantial overtime, this outcome agreed with studies of (31,32) who reported that pudendal nerve regeneration positively influences urinary function and can improve detrusor pressure.

Bladder Capacity (BC)

At 4th week PO, the mean BC in control group was lower than in control group, because the neurotmesis can significantly impact the BC due to its role in bladder control and external urethral sphincter function, this result agreed with studies (33) who found that pudendal nerve injury leads to significant reductions in BC indicating impaired bladder function. At 16th week PO, there was a much larger difference between the two groups, treated group had a higher BC compared to control group, showing a strong treatment effect over time, and this result agreed with (34,35) who indicated the regeneration of the pudendal nerve which has been shown to increase BC in experimental settings and can improve bladder function.

Bladder Compliance (BCom)

At 4th week PO, lower BCom in control group in comparison to normal ranges which can be around 2.75 ±0.51 to 4.98 ±2.15 ml/cmH2O (36), revealed through cystometry indicated a reduced ability of the bladder to accommodate increasing volumes of the urine without a significant raise in internal pressure (abdominal and vesical

pressure). Pudendal nerve damage may contribute to bladder dysfunction, including altered compliance. Researches involved neurotmesis of pudendal nerve in rat models have demonstrate that the pudendal nerve injury can affect both continence mechanism and bladder storage function (37). At 16th week PO, there was a much larger difference between the two groups. Treated group had a higher BCom compared to control group, indicating that the treatment had a progressively stronger effect on BCom overtime, this result agreed with studies (25,38) who found that stimulation of pudendal nerve has been linked to functional recovery from stress urinary incontinence indicating that regeneration of pudendal nerve can restore BCom.

Leak Point Pressure (LPP)

At 4th and 16th week PO, treated group had a higher mean of LPP compared to control group which had much lower mean of LPP. This revealed that the treatment led to improvement in LPP over time, this result agreed with studies (25) who approved that regeneration of pudendal nerve led to return of LPP to normal levels. Whereas the control group showed a significant decline in LPP compared to normal ranges (12.8 ± 2.2 to 33.7 ± 6.6 ml/cmH2O) (39), because the diminish urethral resistance due to compromised function of external urethral sphincter led to reduce LPP (40), this outcome agreed with a study of pudendal nerve neurotmesis in female rat which revealed decrease in LPP (41).

Frequency (Leaks)

At 4th week PO, the mean urinary frequency in control group was higher than treated group, because the pudendal nerve innervates the external urethral sphincter, its injury leads to diminished sphincter control, resulting in urine leakage during activities that increase intra-abdominal pressure, this result was in consent with studies of (33,42) who reported that pudendal nerve injury in rats demonstrated increased urinary frequency and decreased leak point pressures, indicating that pudendal nerve injury can lead to both increased leakage episodes and reduced urethral resistance. At 16th week PO, the difference between the two groups became even more pronounced. Treated group had no urinary frequency, while control had a higher urinary frequency, indicating that the treatment had a strong long-term effect in eliminating urinary frequency, this result agreed with the study (43) who indicated that regeneration of pudendal nerve can lead to reinnervation of external urethral sphincter and maintaining continence.

Conclusions

Early end-to-end coaptation following pudendal nerve neurotmesis significantly improved external urethral sphincter function and bladder-sphincter coordination in female rabbits. Treated animals demonstrated enhanced urinary control and exhibited normalized cystometric parameters, indicating improved functional recovery. These findings support the efficacy of early surgical repair in promoting pudendal nerve regeneration and restoring EUS function and urinary continence after nerve injury.

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Conflict of interest

There is no conflict of interest.

References

1. Murtazina A, Adameyko I. The peripheral nervous system. Development. 2023;150(9):dev201164. DOI: 10.1242/dev.201164
2. Lavorato A, Aruta G, De Marco R, Zeppa P, Titolo P, Colonna MR, Galeano M, Costa AL, Vincitorio F, Garbossa D, Battiston B. Traumatic peripheral nerve injuries: a classification proposal. J Orthop Traumatol. 2023;24(1):20. DOI: 10.1186/s10195-023-00695-6
3. El Homsi M, Zadeh C, Charbel C, Alsheikh Deeb I, Gharzeddine K, Rebeiz K, Hourani R, Khoury N, Moukaddam H. Neurologic pathologies of the vertebral spine. Skeletal Radiol. 2024;53(3):419–36. DOI: 10.1007/s00256-023-04428-y
4. Zapletal J, Nanka O, Halaska MJ, Maxova K, Hajkova Hympanova L, Krofta L, Rob L. Anatomy of the pudendal nerve in clinically important areas. Surg Radiol Anat. 2024;46(2):211–22. DOI: 10.1007/s00276-023-03285-7
5. Giulioni C, Pitoni L, Fuligni D, Beltrami M, Passarella V, Palantrani V, De Stefano V, Castellani D, Galosi AB. Pudendal nerve neurolysis outcomes in entrapment. Investig Clin Urol. 2024;65(3):230–39. DOI: 10.4111/icu.20230402
6. Mohamed S, Hassan H, Omran A, Ramadan E. Effect of urinary incontinence on women's physical condition. J Community Med Public Health Rep. 2024;5(2):1–5. DOI: 10.38207/JCMPHR/2024/JAN05020314
7. Falceto MV, Caccamo R, Garrido AM, Pisu MC, Tejedor MT, Trerotoli P, Rota A, Zambelli D. International survey on canine urinary incontinence. Front Vet Sci. 2024;11:1360288. DOI: 10.3389/fvets.2024.1360288
8. Herman ZJ, Ilyas AM. Sensory outcomes in digital nerve repair. Hand. 2020;15(2):157–64. DOI: 10.1177/1558944719844346
9. Standring S. The history of nerve repair. In: Phillips JB, Tubbs RS, editors. Peripheral nerve tissue engineering and regeneration. Switzerland: Springer; 2022. 1–32 p.
10. Siemionow M, Brzezicki G. Current techniques in peripheral nerve repair. Int Rev Neurobiol. 2009;87:141–72. DOI: 10.1016/S0074-7742(09)87008-6
11. Pereira CT, Hill EE, Stasyuk A, Parikh N, Dhillon J, Wang A, Li A. Molecular basis of nerve repair techniques. J Clin Med. 2023;12(4):1555. DOI: 10.3390/jcm12041555
12. Wang C, Chen Y, Chen X, Hu C, Chen J, Guo A. Antiviral activity of ivermectin against bovine herpesvirus. Animals. 2023;13(20):3164. DOI: 10.3390/ani13203164
13. Henke J, Astner S, Brill T, Eissner B, Busch R, Erhardt W. Intramuscular anaesthetic combinations in rabbits. Vet Anaesth Analg. 2005;32(5):261–70. DOI: 10.1111/j.1467-2995.2005.00242.x
14. Chapple CR, Hillary CJ, Patel A, MacDiarmid SA. Urodynamics made easy. 4th ed. USA: Elsevier; 2018:23–83 p.

15. IBM Corp. IBM SPSS statistics for Windows, version 26. Armonk (NY): IBM Corp; 2019. DOI: 10.4324/9780429056765
16. Wan EL, Dellon AL. Injury to pudendal nerve branch in men. Microsurgery. 2018;38(2):172–76. DOI: 10.1002/micr.30262
17. Portillo FJ, Osmonov DK, Seif C, Braun PM, Boehler G, Alken P, Juenemann KP. Restoration of urethral sphincter function in rabbits. J Urol. 2004;171(4):1715–19. DOI: 10.1097/01.ju.0000116124.58457.b4
18. Grahn PJ. Intraspinal microstimulation strategies [PhD dissertation]. USA, Rochester (MN): Mayo Clinic; 2015. 171 p.
19. Herroelen S, Knowles C, Kerrigan-Smith J, Noone T, Denison T, De Wachter S. Pudendal nerve stimulation for urinary symptoms. Continence. 2024;11:101685. DOI: 10.1016/j.cont.2024.101685
20. Chess-Williams R, McDermott C, Sellers DJ, West EG, Mills KA. Psychological stress and urinary symptoms. LUTS. 2021;13(4):414–24. DOI: 10.1111/luts.12395
21. Stanton SL. Stress urinary incontinence. In: Bock GR, Whelan J, editors. Neurobiology of incontinence. USA: Wiley; 1990. 182–94 p.
22. de Groat WC, Yoshimura N. Recovery of urinary tract function after spinal injury. Prog Brain Res. 2006;152:59–84. DOI: 10.1016/S0079-6123(05)52006-1
23. de Groat WC, Yoshimura N, Furuta A, Kita M, Suzuki Y, Egawa S, Chancellor MB. Association of overactive bladder and stress urinary incontinence. Am J Physiol Regul Integr Comp Physiol. 2008;294(6):R1510–16. DOI: 10.1152/ajpregu.00675.2007
24. Yoshimura N, Chancellor MB. Neurophysiology of lower urinary tract. Rev Urol. 2003;5(8):S3–S10. [available at]
25. Jiang HH, Song QX, Gill BC, Balog BM, Juarez R, Cruz Y, Damaser MS. Electrical stimulation promotes recovery in rats. Am J Physiol Renal Physiol. 2018;315(6):F1555–64. DOI: 10.1152/ajprenal.00431.2017
26. Maher S, Gerber D, Balog B, Wang L, Kuang M, Hanzlicek B, Damaser MS. Pudendal nerve injury in rat model. Sci Rep. 2024;14(1):7444. DOI: 10.1038/s41598-024-57493-1
27. Peng CW, Chen JJ, Cheng CL, Grill WM. Pudendal afferents in voiding efficiency. Am J Physiol Regul Integr Comp Physiol. 2008;294(2):R660–72. DOI: 10.1152/ajpregu.00270.2007
28. Ahn H, Lin DL, Esparza N, Damaser MS. Pudendal nerve injury and leak-point pressure. J Rehabil Res Dev. 2005;42(1):109–14. [available at]
29. de Groat WC, Yoshimura N. Plasticity in urinary reflex pathways. Exp Neurol. 2012;235(1):123–32. DOI: 10.1016/j.expneurol.2011.05.003
30. Sand PK, Ostergard DR. Pelvic floor stimulation and detrusor activity. In: Sand PK, Ostergard DR, editors. Urodynamics and evaluation of female incontinence. UK: Springer; 1995. 125–27 p.
31. Chamorro MV, Salinas-Casado J, Zarza-Lucianez D, Mendez-Rubio S, Pelaquim H, Esteban-Fuertes M. Pudendal innervation in overactive bladder. Actas Urol Esp. 2012;36(1):37–41. DOI: 10.1016/j.acuro.2011.07.011
32. Sakamoto K, Smith GM, Storer PD, Jones KJ, Damaser MS. Neuroregeneration after pudendal nerve crush. Neurourol Urodyn. 2000;19(3):311–21. DOI: 10.1002/(SICI)1520-6777(2000)19:3<311::AID-NAU11>3.0.CO;2-6
33. Furuta A, Kita M, Suzuki Y, Egawa S, Chancellor MB, de Groat WC, Yoshimura N. Overactive bladder after nerve ligation. Am J Physiol Regul Integr Comp Physiol. 2008;294(5):R1510–16. DOI: 10.1152/ajpregu.00497.2007
34. Hokanson JA, Langdale CL, Sridhar A, Grill WM. Pudendal nerve stimulation increases bladder capacity. Am J Physiol Renal Physiol. 2018;314(4):F543–50. DOI: 10.1152/ajprenal.00373.2017
35. Langdale CL, Hokanson JA, Milliken PH, Sridhar A, Grill WM. Pelvic nerve stimulation increases bladder capacity. Am J Physiol Renal Physiol. 2020;318(6):F1357–68. DOI: 10.1152/ajprenal.00579.2019
36. Chen HD, Ye XT, Zhang YR, Weng ZL, Li CD. Sildenafil effects on bladder compliance. Zhonghua Yi Xue Za Zhi. 2012;92(38):2720–23. DOI: 10.3760/cma.j.issn.0376-2491.2012.38.016
37. Yang X, Wang X, Gao Z, Li L, Lin H, Wang H, Zhang Y, Liu J. Anatomical pathogenesis of stress urinary incontinence in women. Medicina. 2022;59(1):5. DOI: 10.3390/medicina59010005
38. Seif C, van der Horst C, Naumann CM, Junemann KP, Bosch R, Buller J, Braun PM. Chronic pudendal neurostimulation in overactive bladder. Aktuelle Urol. 2005;36(3):234–38. DOI: 10.1055/s-2004-830204
39. Skaff M, Pinto ER, Leite KR, Almeida FG. Rabbit urethral sphincter deficiency model. Int Braz J Urol. 2012;38(1):17–24. DOI: 10.1590/S1677-55382012000100003
40. Weber AM. Leak point pressure measurement and stress urinary incontinence. Curr Womens Health Rep. 2001;1(1):45–52. [available at]
41. Khorramirouz R, Mozafarpour S, Kameli SM, Ladi Seyedian SS, Oveisi N, Rahimi Z, Alijani M, Kajbafzadeh AM. Novel method of urinary sphincter deficiency in rats. Anat Rec. 2016;299(2):173–80. DOI: 10.1002/ar.23291
42. Sajadi KP, Gill BC, Damaser MS. Neurogenic aspects of stress urinary incontinence. Curr Opin Obstet Gynecol. 2010;22(5):425–29. DOI: 10.1097/GCO.0b013e32833e499d
43. Balog BM, Deng K, Askew T, Hanzlicek B, Kuang M, Damaser MS. Brain-derived neurotrophic factor and continence recovery. Int J Mol Sci. 2023;24(5):4998. DOI: 10.3390/ijms24054998

تقييم تجدد العصب الفرجي بعد قطعه الكامل في نموذج الأرنب

رانيا خضر خليفة الجبوري و حميد علي كاظم التميمي

فرع الجراحة والتوليد، كلية الطب البيطري، جامعة بغداد

الخلاصة

يلعب العصب الفرجي دورًا حيويًا في تعصيب المصرة الإحليلية الخارجية، مسهمًا بذلك في التحكم البولي وتنسيق عمل المثانة مع المصرة الإحليلية الخارجية. هدفت هذه الدراسة إلى تقييم تأثير قطع العصب الفرجي الكامل مع أو بدون إجراء توصيل نهائي للطرفين على وظيفة المصرة الإحليلية الخارجية وتنسيقها مع المثانة. تم توزيع عشرين أرنبًا أنثى من نوع نيوزيلاندا الابيض وبصحة جيدة بشكل عشوائي إلى مجموعتين. في المجموعة الضابطة، تم إجراء قطع كامل للعصب الفرجي دون أي تدخل لاحق. أما في المجموعة المعالجة، فقد تم إجراء قطع للعصب الفرجي تلاه توصيل نهائي مباشر للطرفين. تم إجراء التقييم السريري أسبوعيًا بعد العملية الجراحية من خلال حساب يوميات المثانة مرة واحد أسبوعيا واستمر الحساب لمدة ٢٤ ساعة في كل مرة، والتي شملت: عدد نوبات السلس، كمية السوائل اليومية المتناولة، حجم كل تبول، والفترة الزمنية بين كل عملية تبول، وذلك لمراقبة أنماط التبول والتغيرات السلوكية. كما تم اجراء اختبار قياس المثانة في الأسبوعين الرابع والسادس عشر بعد العملية، وشمل: ضغط العضلة النافصة للمثانة، السعة المثانية، امتثال جدار المثانة، ضغط نقطة التسريب، وتكرار التسريب، وذلك لقياس ديناميكية المثانة والاستجابات الفسيولوجية. أظهرت النتائج وجود فروق معنوية عالية بين مجموعة السيطرة والمجموعة المعالجة، سواء في تقييمات يوميات المثانة أو في مؤشرات تخطيط المثانة. وتؤكد هذه النتائج أن الخياطة الطرفية المباشرة للعصب الفرجي تُسهم في تعزيز تجدد العصب وظيفيًا من خلال استعادة السيطرة على المصرة العاصرة الخارجية للإحليل.