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ORIGINAL PAPER

Assessment of feasibility of neuronal reinnervation of pudendal nerve by femoral nerve's motor branch to vastus lateralis: an ultrasound-guided study

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Abstract

Background Injury to the pudendal nerve leads to bowel/bladder incontinence which compromises the quality of life in these patients. Many peripheral nerves have been used to neurotize the pudendal nerve in order to regain bladder continence. The aim of this study was to assess the anatomic feasibility, by ultrasound, of transfer of the femoral nerve's motor branch to the vastus lateralis (MNVL) to the pudendal nerve for restoring continence.

Methods Thirty healthy male volunteers were randomly selected, irrespective of age. The origin of MNVL was traced in the distal thigh, to the level the nerve was visible using high-frequency ultrasound probe. The length of the nerve was measured with the help of a measuring tape. The pudendal nerve was identified just medial to the ischial tuberosity on the same side. The distance between the origin of MNVL and the pudendal nerve was measured. The same procedure was performed in the opposite side.

Results MNVL has enough length and calibre to neurotize the pudendal nerve in 28/30 (93.33%) individuals on the right side, and in 29/30 (96.66%) individuals on the left side.

Conclusions On ultrasonography, length of MNVL was found sufficient to reach the pudendal nerve in majority of the patients. USG can be a tool to assess the feasibility of transfer of MNVL to the pudendal nerve.

Level of evidence: Level IV, risk/prognostic study.

Keywords Neuronal reinnervation · Pudendal nerve · Femoral nerve · Motor branch · Ultrasound · Continence

Introduction

The pudendal nerve supplies pelvic muscles including the external urethral/anal sphincters and controls the continence in coordination with autonomic nervous system. Injury to the pudendal nerve leads to bowel/bladder incontinence which compromises the quality of life of patients [1]. Branches of femoral nerve and other peripheral nerves have been used to neurotize the pudendal nerve in order to regain bladder continence [2]. The aim of this study was to evaluate if USG can be used to assess the anatomic feasibility of transfer of MNVL to the pudendal nerve.

Material and Methods

This study was conducted in the Department of Surgery and Department of Radio diagnosis at a tertiary referral centre in Central India over a period of 2 years. Before starting the study, Institutional Ethical Committee approval was obtained and written informed consent was taken from all the volunteers and their parents in the case of minors. Probe of frequency range 7.3–11.8 MHz and linear transducer in the superficial/musculoskeletal setting of Siemens Acuson 300

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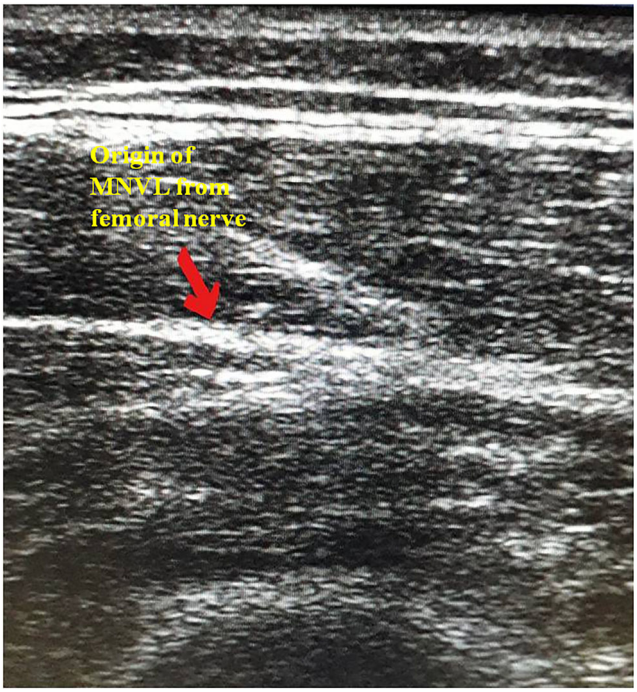

Fig. 1 The origin of MNVL from femoral nerve

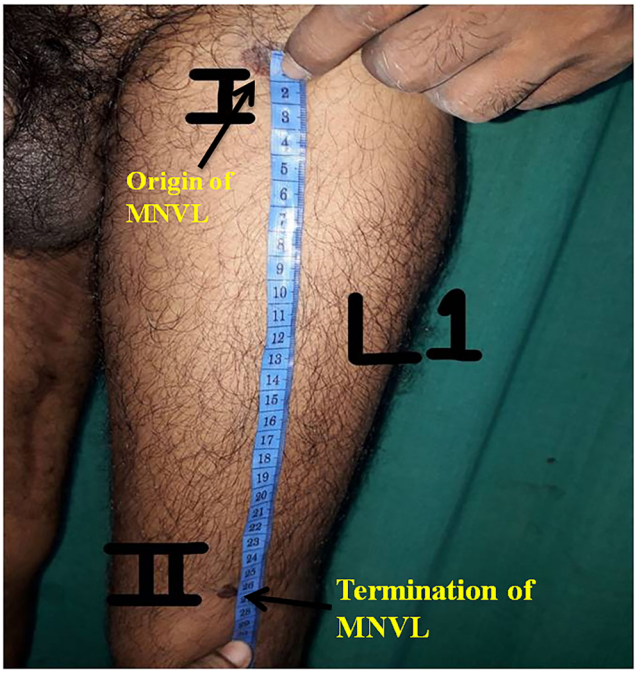

Fig. 2 The length of MNVLM

USG machine were used for combination of grey scale and colour Doppler assessment.

Thirty healthy male volunteers were randomly selected, irrespective of age. We did not have any female in this study as India is a very conservative country and female subject did not volunteer for the study; therefore, we cannot comment on information regarding female patients. These volunteers were inspected for any pelvic/gluteal and thigh region deformity. All volunteers were explained the procedure in detail. The volunteer was placed in supine position with knee extended; the femoral artery was located by USG and followed distally. The lateral circumflex femoral artery is commonly located between the rectus femoris and the vastus lateralis muscles, along a line between the anterior superior iliac spine and the lateral aspect of the patella, corresponding to the lateral inter-muscular septum. Lateral to lateral circumflex femoral artery is the distal branch of nerve to vastus lateralis which is readily visible using high-frequency ultra sound probe. After identifying the femoral nerve, the origin of the nerve to the vastus lateralis from the femoral nerve (point I) was identified (Fig. 1). The nerve to the vastus lateralis was traced in the distal thigh, to the level the nerve was visible and that point was marked as II. The distance (L1) between marks I and II was measured with the help of a measuring tape (Fig. 2).

Next volunteers were instructed to lie in prone position. Pudendal nerve was identified just medial to the ischial tuberosity and pudendal artery and marked as point III. The distance between the marks I and III were measured. The distance between mark I and mark II is the length of the nerve to the vastus lateralis. The distance between mark I and mark III (L2) is the length required for the nerve to the vastus lateralis to reach the pudendal nerve (Fig. 3). Calibre of the nerves to the vastus lateralis at origin, at termination and of the pudendal nerve medial to ischial tuberosity were also measured (Fig. 4). The same procedure was performed on the opposite side and all measurements were noted.

Results

Thirty healthy male volunteers were included in this study; their average age was 28.13 years (range 17–45 years). Mean length of motor branch to vastus lateralis was 27.21 cm on the right side and 27.18 cm on the left side. The mean distance between origins of motor branch to the vastus lateralis to the pudendal nerve was 25.63 cm on the right side and 25.61 cm on the left side (Table 1). Motor branch to the vastus lateralis has enough length to reach pudendal nerve on the right side in 28/30 (93.33%) and on left side 29/30 (96.66%) individuals (Table 2). Mean calibre of the motor branch to the vastus lateralis at origin was 4 mm, at termination 3 mm, and the calibre of the pudendal

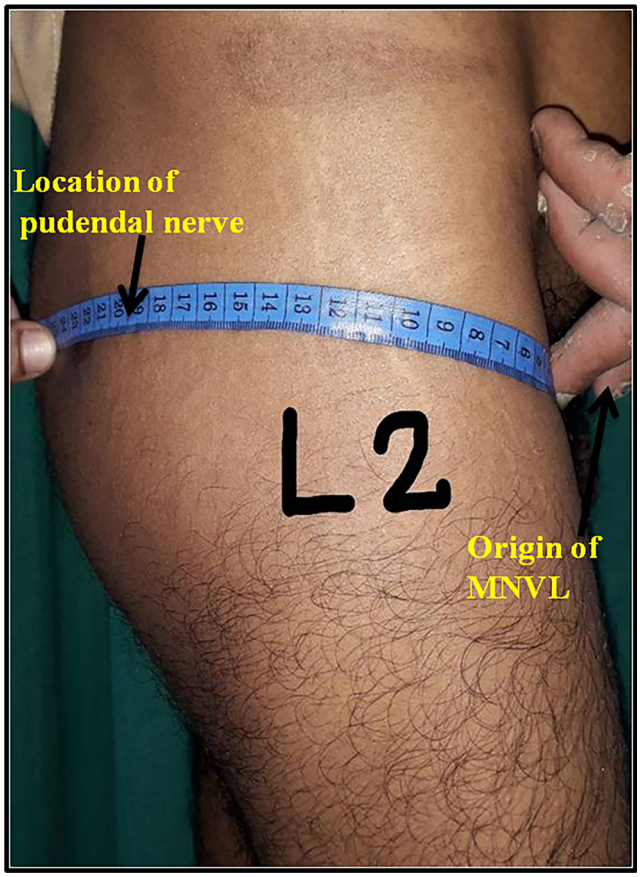

Fig. 3 The distance between origin of MNVL and pudendal nerve

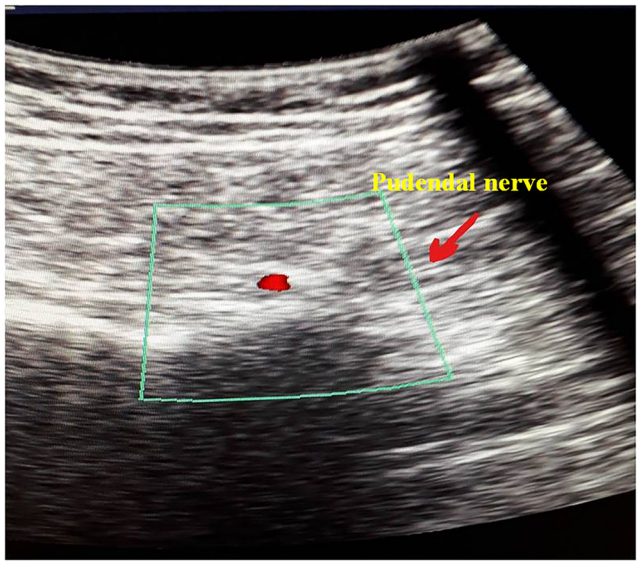

Fig. 4 The pudendal nerve medial to ischial tuberosity

nerve was 2.7 mm on the right side. On the left side, the calibre of nerves were 3.9 mm, 2.8 mm and 2.8 mm.

Discussion

Restoration of bladder-bowel function is among the top two priorities in quality of life (QOL) studies performed in lower spinal cord injury patients [3]. Other causes for urinary and faecal incontinence are damage to sacral roots following sacral tumours, lesions of the conus medullaris, cauda equine syndrome, sacral meningomyelocele and pelvic surgeries. The pudendal nerve may also get damaged during surgery for ischiorectal abscess/fistula, haemorrhoids and pudendal canal decompression [4–6]. Many cadaveric and animal studies have shown the anatomical feasibility of using peripheral nerves like the sciatic, femoral and obturator nerves to neurotize the pudendal nerve in an attempt to restore bladder/bowel continence in lower motor neuron lesions and isolated pudendal nerve injury [2, 7–9]. Success of such reinnervations has been objectively demonstrated in animal experimentation studies by nerve-evoked detrusor contractions and retrograde labelling techniques [8, 10].

In such endeavours, the major concern is always about adequate length of the 'donor' nerve to reach the pudendal nerve, and traditionally cadaveric dissections are used to evaluate such an anatomical feasibility [2, 7–11]. Cadaveric dissection gives better appreciation of three-dimensional anatomy; however, scarcity of cadavers, high cost of their preservation, deleterious effects of embalming materials on human beings, and emotional and ethical issues with their use prompted us to find an alternate technique to assess the anatomy/length of 'donor' nerve and feasibility of such a potential nerve transfer [12, 13].

Advent of high-resolution ultrasonography has provided an inexpensive, reliable, portable, reproducible, non-invasive and real-time/dynamic diagnostic technique for imaging of peripheral nerves. Its concomitant use with Doppler mode aids in localization of the target nerve by identifying accompanying vessels [14, 15]. Additional benefit of using ultrasound is the ability to assess the feasibility of nerve in a particular patient, where nerve transfer has been planned rather than assuming the nerve will reach to target nerve based on previous cadaveric studies. MNVL has been studied as an inter-positional nerve graft for facial nerve rehabilitation because of its length and other anatomical features [16]. We evaluated the efficacy of USG to image and measure the length of MNVL for feasibility of neuronal reinnervation of pudendal nerve.

The idea of neurotization of pudendal nerve is superior to other nerve transfers because it is a distal neurotization, and continence may be regained in a short period of time. The

Table 1 The distance between origins of the motor branch to the vastus lateralis to the pudendal nerve

S no.	Age/sex	Right lower limb		Left lower limb		Remark
		L1	L2	L1	L2	
1	28/M	28	26.5	26.5	25	Bilateral nerve transfer feasible
2	34/M	27.5	27	26.5	25	Bilateral nerve transfer feasible
3	33/M	27	26	29	27.5	Bilateral nerve transfer feasible
4	29/M	22	26	22	26	Not feasible on both sides
5	20/M	30	28	30.5	30	Bilateral nerve transfer feasible
6	21/M	28	27	29	27	Bilateral nerve transfer feasible
7	24/M	27	25	28	27	Bilateral nerve transfer feasible
8	35/M	26.5	25.5	27.5	27	Bilateral nerve transfer feasible
9	27/M	30	29	27	26	Bilateral nerve transfer feasible
10	23/M	26.5	26	27	26.5	Bilateral nerve transfer feasible
11	22/M	28	27.5	27.5	25	Bilateral nerve transfer feasible
12	17/M	32	31	27	25	Bilateral nerve transfer feasible
13	24/M	27	25	27	25.5	Bilateral nerve transfer feasible
14	21/M	29	27	30	28	Bilateral nerve transfer feasible
15	36/M	26.5	23	24	23	Bilateral nerve transfer feasible
16	24/M	28	27	29	27	Bilateral nerve transfer feasible
17	45/M	26.5	26	27.5	27	Bilateral nerve transfer feasible
18	30/M	29	27	28	27	Bilateral nerve transfer feasible
19	35/M	25	26.5	27	26	Feasible only on right side
20	20/M	26	24	27	26	Bilateral nerve transfer feasible
21	26/M	29	26.5	28.5	27	Bilateral nerve transfer feasible
22	35/M	26	23	27.5	24	Bilateral nerve transfer feasible
23	33/M	27	25.5	27	26.5	Bilateral nerve transfer feasible
24	28/M	28	25.5	26	26	Bilateral nerve transfer feasible
25	34/M	30	25	33	25.5	Bilateral nerve transfer feasible
26	35/M	25.5	22.5	26.5	23.5	Bilateral nerve transfer feasible
27	26/M	24	23.5	25	22.5	Bilateral nerve transfer feasible
28	27/M	26	23	25.5	23.5	Bilateral nerve transfer feasible
29	24/M	24.5	22	23.5	22	Bilateral nerve transfer feasible
30	28/M	27	22.5	26	21.5	Bilateral nerve transfer feasible

peripheral nerves like hypogastric, obturator, and genitofemoral and branches from femoral nerves and sciatic nerve have tried to neurotize the pudendal nerve in animals, cadavers and human studies leading to varying degrees of success [2, 8–10]. The femoral nerve may be a good choice to neurotize pudendal nerve because its fascicular anatomy

Table 2 Feasibility of nerve transfer on both sides

S no.	Side	Feasibility of nerve transfer	
		No. of individuals	Percentage (%)
1	Right	28	93.33
2	Left	29	96.66
3	Bilateral	28	93.33

suggests that it has enough number of motor axons and has a constant branching pattern [17]. Barbe et al have used the femoral nerve's motor branch to the vastus medialis muscle to neurotize the pudendal nerve [2]. However, limitation of using vastus medialis is that it is an important muscle for active knee extension that contributes significantly to medial patellar stability and daily weight-bearing activities [18].

Hence, we hypothesized using MNVL to neurotize the pudendal nerve. MNVL commonly has two divisions; proximal division enters the vastus lateralis muscle while the distal division continues to course distally along the antero-medial border of the lateralis muscle with the descending branch of the lateral circumflex femoral artery. Harvesting of the distal branch of MNVL has several advantages as a potential 'donor' nerve: it is a motor nerve which has a consistent anatomy and has an adequate length to reach pudendal nerve, and its harvest/sacrifice does not clinically lead to donor site complications/impaired overall lower extremity function [16, 19, 20].

In our study, the distance between the nerve to the vastus lateralis and the pudendal nerve was measured by USG, on both sides in 30 healthy volunteers. It was shown that MNVL had sufficient length in 28/30 volunteers on the right side and 29/30 volunteers on the left side to be transferred to the pudendal nerve without tension (Table 2). It must be emphasized that this is the first study to hypothesize the use of MNVL for such neurotization and to successfully assess its anatomical feasibility—without cadaveric dissection—by using high-frequency USG imaging.

Conclusions

On ultrasonography, length of MNVL was found sufficient to reach the pudendal nerve in majority of the patients. USG can be used as an alternative tool to cadaveric dissection to assess the feasibility of such a transfer to the pudendal nerve.

Compliance with ethical standards

Conflict of interest Pawan Agarwal, Geetesh Ratre, Sanjoy Pandey and D. Sharma declare that they have no conflict of interest.

Ethical approval Institutional ethical committee approval taken.

Informed consent Informed consent was obtained from patients and their parents in cases of minor.

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