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*Original article*

# Gait analysis after neurorrhaphy in the brachial plexus

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## Abstract

The gait is a form of human and animal locomotion on land by using limbs. The study assessed functional recovery after end to side and side to side neurorrhaphy the ventral branches of the C5 and C6 spinal nerves to the C7 spinal nerve on the rabbit brachial plexus. Gait statistical analysis showed significant differences between the control group versus the end-to-side and side to side neurorrhaphy groups, in opposite to the comparison between the two experimentals groups. Gait analysis results corresponded with the histomorphometric results. The results indicate the potential use of gait analysis for the assessment of the recovery of nerve function.

**Key words:** gait analysis, spinal nerve, neurorrhaphy

## Introduction

The results of attempts to repair peripheral nerves are still unsatisfactory (Dahlin 2008). The basic method of the treatment of the interruption of the nerve is direct suture (end to end). In cases of large gap we use the procedure of coaptation end-to-side (Viterbo et al. 1992, Lundborg et al. 1994). End-to-side neurorrhaphy has been dedicated as a way to increase the number of regenerating fibers by collateral sprouting from the donor nerves (Xiong

et al. 2003, Kubek et al. 2004). The major question with using an uninjured donor nerve in end-to-side repairs is whether a sufficient number of fibers by collateral sprouting could be enticed to grow into the regenerating nerve without damaging the donor nerve (Kovacic et al. 2007). The main problem is the assessment of the effectiveness of each method. Previous studies are mainly based on histological and electromyographic studies. These results do not always correlate with the functional outcome. The purpose of this study is to present a new technique neurorrhaphy

side to side and the evaluation of the results was based on gait analysis.

The gait is a form of human and animal locomotion on land by using limbs. This is a series of cycling movements of the whole body. This analysis is one of the elements of a medical examination to assess the locomotion system. Gait analysis provides information about integration the skeletons, muscles, joints and nervous system. Gait analysis is also a useful test for the evaluation of the pain degree (Coulthard et al. 2002). It is an important tool in the assessment of the level of neurological disorders of the brain, spinal and peripheral nerve. Frequently gait analysis is performed by using advanced computer analysis techniques (McLaughlin 2001, Fanchon and Grandjean 2009). However, visual analysis of gait and footprint stride length assessment seems to be useful (Guillot et al. 2008). We believe that confirmation of the effectiveness of this method will complement the existing methods used in assessing neuroorrhaphy.

## Materials and Methods

The experiments were approved by the II Local Ethics Committee for animal at the University of Life Sciences in Wrocław. Thirty six New Zealand White rabbits were anesthetized and surgical procedure on the left brachial plexus (C5-ventral branches of spinal nerve C5, C6-ventral branches of spinal nerve C6, C7-ventral branches of spinal nerve C7) was performed. Premedication was performed with medetomidine (Cepetor) at a dose 150 µg/kg body weight, butorphanol (Torbugesic) at a dose of 0.2 mg/kg body weight and ketamine (Bioketan) at a dose of 35 mg/kg body weight. General anesthesia was performed with propofol, which was administered continuously at a dose of 0.1/mg/kg/min. The analgesic effect was supported by fentanyl at a dose of 2-3 mcg/kg. After the procedure, buprenorphine (Vetergesic) was used at a dose of 20 mcg/kg i.m. every eight hours. The animals were given meloxicam (Metacam) at 0.2 mg/kg body weight for two days after surgery. The same anesthesia protocol for all the rabbits was used. In 12 cases, end to side neuroorrhaphy (C5, C6 to C7), in 12 cases, side to side neuroorrhaphy (C5, C6 to C7), in 6 cases only cut (C5, C6) without suture were made. The control group consisted of 6 normal rabbits. C5 and C6 were arulsed incised after exiting the spinal canal. End-to-side repair was made by a 3-mm window on C7, and distal stump was sutured by 2 10-0 ethilon stitches by a 3-mm. Side-to-side repair was made by a 3-mm window on the right side of C5, C6, and distal stump was sutured by 2 10-0 ethilon stitches by a 3-mm window on the left side C7. Evaluation was

performed 20 weeks after surgery. The assessment covered the position, posture and gait analysis. Neurological examination was performed including, proprioception, spinal reflexes and superficial and deep pain sensation. The six healthy rabbit not subjected to any medical procedures was the model for correct neurological response, body posture and position and gait traces. Inked-paw stride length was performed as described (Tillerson et al. 2002, Guillot et al. 2008). The front paws were inked and the rabbits were allowed to walk toward the paper without stimulation. Toe-to-toe measures were taken (the length of each forepaw step was measured) and averaged. The averaged length was calculated by summing the distance for each step and then dividing by the number of successful steps. The neurological examination was performed. Efficiency in the neuroorrhaphy was made on the basis of histological analysis of the number of myelinated fibers and a factor of g-ratio (the ratio of the axon diameter to the diameter of the entire fiber).

## Results

The comparison of material collected from C5, C6 1 cm after coaptation to material from C5, C6 on the same level in the control group revealed that the number of myelinated axons was markedly reduced accordingly compared to control group: in end to side -47%, in side to side group -36 %. G-ratio was respectively  $0.6589 \pm 0.08$  in end to side neuroorrhaphy group,  $0.6318 \pm 0.09$  in side to side neuroorrhaphy group compared to  $0.6559 \pm 0.08$  in normal group.

Gait analysis results are shown in Table 1. Gait statistical analysis (Student test) showed significant differences between control group versus end to side ( $t=0.00948$ ,  $p<0.05$ ) and side to side ( $t=0.00013$ ,  $p<0.05$ ) group, in opposite to the comparison between the two groups with neuroorrhaphy ( $t=0.05779$ ,  $p<0.05$ ). These results corresponded with the results of histological studies.

## Discussion

The number of myelinated axons observed in the experimental group is lower than that found in others studies, compared with end-to-side coaptation, e.g. between the peroneal and tibial nerves, approximately 50-63% of the original number of axons are present in the recipient nerve (Liao et al. 2009). On the other hand, the G-ratio was similar. As reported (Chomiak and Hu 2009, Rushton 1951) the G-ratio in the central nerve system in rats is near 0.7, and in the periph-

Table 1. Evaluation at 20 weeks after surgery.

	Control group	Without neurorrhaphy	Side to side neurorrhaphy	End to side neurorrhaphy
Position and posture	Correct	Invalid Limb after surgery dissuaded from the body axis by 45 degrees	Invalid Operated limb slightly dissuaded from the body axis	Invalid Operated limb slightly dissuaded from the body axis
Gait	Correct	Walking in a circle, No active support on the affected limb	Invalid, The animal was able to move forward and get to the destination, noted a delay in the movement of the affected limb and extension of the support phase	Invalid but the animal was able to move forward and get to the destination, noted a delay in the movement of the affected limb and extension of the support phase
Neurological examination	The withdrawal response, Deep and superficial and deep pain sensation also correct	No withdrawal response and deep pain sensation	The withdrawal response correct, Impaired superficial pain sensation deep pain sensation also correct	The withdrawal response correct Impaired superficial pain sensation deep pain sensation also correct
Averaged stride length	18.16 ± 1.47 cm	Non	13.83 ± 1.85 cm	15.41 ± 2.02 cm

erial nerve more than 0.6. These histological analysis results confirm the effectiveness of the method.

The present study was carried out to evaluate the return of the motor function after nerve neurorrhaphy. The step length on the affected side was noticeably shorter than on the healthy side. The trace of the experimental group had impaired symmetries and imbalance in the distribution of the body weight, but there was no difference between the footsteps in the side to side and end to side group.

The clinical symptoms of the nerve plexuses and peripheral nerve injuries include the loss of muscle mass and muscle function, sensory disturbances and motor function deficits (Evans et al. 1999). The computerized gait analysis systems are recommended as a more efficient, sensitive, and reliable way to measure motor deficits. However, investigations performed by Guillot et al. have proved that in this case the stride length test is more sensitive. The stride length test – average forepaw step distance in a study conducted by Tillerson demonstrated the usefulness of this test. The gait analysis is one of three (histomorphometry, electrophysiology and gait analysis) commonly used parameters to assess the nerve regeneration (Munro et al. 1998). The functional tests give us information about motor axon regeneration and show the actual condition of the patient (Varejão et al. 2001). It must also be remembered that pain is an important factor affecting the gait. These results indicate the potential use of gait analysis for the assessment of the recovery of nerve function.

## References

- Chomiak T, Hu B (2009) What is the optimal value of the g-ratio for myelinated fibers in the rat CNS? A theoretical approach. *PLoS One* 4: e7754.
- Coulthard P, Pleuvry BJ, Brewster M, Wilson KL, Macfarlane TV (2002) Gait analysis as an objective measure in a chronic pain model. *J Neurosci Methods* 116: 197-213.
- Dahlin LB (2008) Nerve injuries. *Curr Orthopaed* 22: 9-16.
- Evans GR, Brandt K, Widmer MS, Lu L, Meszlenyi RK, Gupta PK, Mikos AG, Hodges J, Williams J, Güürlek A, Nabawi A, Lohman R, Patrick CW Jr (1999) In vivo evaluation of poly(L-lactic acid) porous conduits for peripheral nerve regeneration. *Biomaterials* 20: 1109-1115.
- Fanchon L, Grandjean D (2009) Habituation of healthy dogs to treadmill trotting: repeatability assessment of vertical ground reaction force. *Res Vet Sci* 87: 135-139.
- Guillot TS, Asress SA, Richardson JR, Glass JD, Miller GW (2008) Treadmill gait analysis does not detect motor deficits in animal models of Parkinson's disease or amyotrophic lateral sclerosis. *J Mot Behav* 40: 568-577.
- Kovacic U, Tomsic M, Sketelj J, Bajrović FF (2007) Collateral sprouting of sensory axons after end-to-side nerve coaptation-a longitudinal study in the rat. *Exp Neurol* 203: 358-369.
- Kubek T, Kyr M, Haninec P, Sámál F, Dubový P (2004) Morphological evidence of collateral sprouting of intact afferent and motor axons of the rat ulnar nerve demonstrated by one type of tracer molecule. *Ann Anat* 186: 231-234.
- Liao WC, Chen JR, Wang YJ, Tseng GF (2009) The efficacy of end-to-end and end-to-side nerve repair (neurorrhaphy) in the rat brachial plexus. *J Anat* 215: 506-521.
- Lundborg G, Zhao Q, Kanje M, Danielsen N, Kerns JM (1994) Can sensory and motor collateral sprouting be

- induced from intact peripheral nerve by end-to-side anastomosis? *J Hand Surg Br* 19: 277-282.
- McLaughlin RM (2001) Kinetic and kinematic gait analysis in dogs. *Vet Clin North Am Small Anim Pract* 31: 193-201.
- Munro CA, Szalai JP, Mackinnon SE, Midha R (1998) Lack of association between outcome measures of nerve regeneration. *Muscle Nerve* 21: 1095-1097.
- Rushton WA (1951) A theory of the effects of fibre size in medullated nerve. *J Physiol* 115: 101-122.
- Tillerson JL, Caudle WM, Reverón ME, Miller GW (2002) Detection of behavioral impairments correlated to neurochemical deficits in mice treated with moderate doses of 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine. *Exp Neurol* 178: 80-90.
- Varejao AS, Meek MF, Ferreira AJ, Patrício JA, Cabrita AM (2001) Functional evaluation of peripheral nerve regeneration in the rat: walking track analysis. *J Neurosci Methods* 108: 1-9.
- Viterbo F, Trindade JC, Hoshino K, Mazzoni Neto A (1992) Latero-terminal neurotomy without removal of the epineurial sheath. Experimental study in rats. *Rev Paul Med* 110: 267-275.
- Xiong G, Ling L, Nakamura R, Sugiura Y (2003) Retrograde tracing and electrophysiological findings of collateral sprouting after end-to-side neurotomy. *Hand Surg* 8: 145-150.