The effect of electrical stimulation of the pudendal nerve on sciatic nerve blood flow in animals

Motohiro Inoue, Tatsuya Hojo, Miwa Nakajima, Hiroshi Kitakoji, Megumi Itoi, Yasukazu Katsumi

Abstract
Objective To investigate the mechanism of the clinical effect of electroacupuncture of the pudendal nerve on the lumbar and lower limb symptoms caused by lumbar spinal canal stenosis, we studied changes in sciatic nerve blood flow during electrical stimulation of the pudendal nerve in the rat.
Methods Using rats (n=5), efferent electrical stimulation to the pudendal nerve was performed and sciatic nerve blood flow was measured with laser Doppler flowmetry. Simultaneously, changes in the blood pressure and cardiac rate were measured. Furthermore, the effect of atropine on these responses to the stimulation was also studied.
Results Electrical stimulation of the pudendal nerve significantly increased blood flow in the sciatic nerve transiently without increasing heart rate and systemic blood pressure. The significant increase in the sciatic nerve blood flow disappeared after administration of atropine.
Conclusion Electrical stimulation of the pudendal nerve causes a transient and significant increase in sciatic nerve blood flow. This response is eliminated or attenuated by administration of atropine, indicating that it occurs mainly via cholinergic nerves.

Keywords
Pudendal nerve, sciatic nerve, blood flow, laser Doppler flowmetry, electrical stimulation, rat.

Introduction
Acupuncture stimulation of the pudendal nerve has been used to treat the symptoms of neurogenic bladder dysfunction and chronic pelvic pain syndrome. In patients with neurogenic bladder dysfunction together with the symptoms of lumbar and lower limb caused by spinal canal stenosis, our clinical experience indicates that, in some cases, pudendal nerve electroacupuncture also relieves or eliminates lumbar and lower limb symptoms. In a companion paper, we describe a case series of patients who received this treatment.

A characteristic symptom of spinal canal stenosis is intermittent claudication, which is thought to be caused by reduced blood flow to the sciatic nerve and the cauda equina. Since we have observed that pudendal nerve electroacupuncture was an effective treatment for patients with low back pain, it is possible that pudendal nerve electroacupuncture in some way influences sciatic nerve blood flow.

Taking the above into consideration, we conducted an animal study in which changes in sciatic blood flow during electrical stimulation of the pudendal nerve in the rat were observed. With the aim of investigating the mechanism involved, the changes in the response to electrical stimulation after administering an autonomic blocking agent were also observed.

Methods
Experimental animal preparation
All experimental procedure in the present study was approved by the Ethics Committee of Meiji University of Integrative Medicine. The laboratory animals used were five Wistar rats (male, 270–330g). They were anaesthetised by intraperitoneal injection of urethane (1.2g/kg). Rectal temperature was monitored with a thermistor, and a heating mat was used to maintain a body temperature of about 37.5±0.3°C. A muscle relaxant (Mioblock, Organon, Tokyo, Japan) was administered by continuous
infusion (2mg/h) with a syringe pump (SCT−525, Termo, Tokyo, Japan), and a tracheal cannula was inserted and connected to a respirator (SN−480−7, Shinano, Tokyo, Japan). To measure blood pressure, a cannula containing a mixture of sodium heparin and saline solution was inserted into a common carotid artery, and blood pressure and instantaneous heart rate were measured over time via a transducer (P23XL, Sanei, Tokyo, Japan). A cannula was also inserted into a common jugular vein for drug administration. A sciatic nerve on one side was then exposed and a laser-Doppler blood flowmetry probe (Type N, Advance, Tokyo, Japan) was placed on it, with a balancer (ALF−B, Advance, Tokyo, Japan) used to maintain a constant contact pressure. Systemic blood flow measured with a time constant of three seconds was recorded with a pen recorder. To prevent drying of the sciatic nerve and peripheral tissue, measurements were conducted in a paraffin oil pool.

**Electrical stimulation of the pudendal nerve**
The pudendal nerve was exposed and amputated in the vicinity of the sacral vertebrae in the gluteal region on the same side as that used for measuring sciatic nerve blood flow. The distal stump was placed on a platinum bipolar electrode, the surrounding area was insulated with paraffin oil and efferent monophasic electrical stimulation was conducted. Square wave stimulation was performed for 40 seconds with a pulse width of 500μs and the intensity of 10V at a frequency of 10 Hz.

**Drug administration**
At least 30 minutes after the first stimulation, when all readings were stable, the muscarinic receptor blocking agent atropine sulphate was administered (1mg/kg, iv) with the objective of investigating the mechanism involved in the response of sciatic nerve blood flow to electrical stimulation of the pudendal nerve. Five minutes after administration, electrical stimulation of the pudendal nerve was repeated and changes in sciatic blood flow were observed.

**Statistical analysis**
All data were expressed as mean values ± standard deviation. For experimental animal data, the values at 10 second intervals for sciatic nerve blood flow, mean blood flow and heart rate were used, mean values at a control time (40 seconds before electrical stimulation) were calculated, and all the data were expressed as rates of change of mean values. Paired t test followed by the Bonferroni correction was applied to detect significant differences between baseline and each measurement in sciatic nerve blood flow, blood pressure and heart rate after electrical stimulation. A P value of less than 0.05 was considered statistically significant.

**Results**
Figure 1 shows the mean changes in the sciatic nerve blood flow during electrical stimulation and again after administration of atropine. Changes observed in sciatic nerve blood flow and fluctuations in blood pressure and heart rate in response to efferent electrical stimulation of the pudendal nerve were similar in all five rats. The mean value for sciatic nerve blood flow increased significantly, reaching a peak 20 seconds after the start of stimulation, with an increase of about 90% observed. Thereafter, blood flow tended to decrease but a significant increase was maintained during the period of stimulation. After ending the stimulation, sciatic nerve blood flow began to decrease rapidly, after 20 seconds returning to the same value as that before stimulation. No significant change was observed in blood pressure or heart rate values during or after stimulation. Five minutes after administration of atropine sulphate (1mg/kg, iv), the significant increase in sciatic nerve blood flow in response to electrical stimulation of the pudendal nerve was eliminated.

**Discussion**
There are favourable reports of acupuncture for lumbar and lower limb symptoms when treatment is given in the vicinity of the compressed nerves. Nevertheless, many cases do not respond favourably to acupuncture treatment of this kind, and there is a need to develop new methods of treatment. We have noted several cases that experienced improvement of the lumbar and the lower limb symptoms due to spinal canal stenosis when pudendal nerve electroacupuncture was conducted with the objective of alleviating neurogenic bladder dysfunction symptoms.

Cauda equina intermittent claudication, a characteristic finding of spinal canal stenosis, is thought to be due to compression ischemia of the
cauda equina, nerve root, sciatic nerve and other areas. If this is the case, and assuming that pudendal nerve electroacupuncture stimulation is effective for intermittent claudication, it is possible that pudendal nerve electrical stimulation in some way influences cauda equina and sciatic nerve blood flow. With the aim of investigating this mechanism of action, we observed changes in sciatic nerve blood flow following electrical stimulation of the pudendal nerve in rats. We showed a transient, significant increase in sciatic nerve blood flow. We also found that administration of atropine eliminated or attenuated this increase in sciatic nerve blood flow, indicating that increased blood flow occurs mainly via cholinergic nerves.

Although these results are somewhat limited because the number of experiments is relatively small, we consider that the results in different animals were consistent enough to confirm the reproducibility of the response to the electrical acupuncture.

These results point to the possibility that electroacupuncture of the pudendal nerve in humans may have an influence on the circulatory dynamics of the sciatic nerve. These transient changes in sciatic nerve blood flow could be involved in the mechanism of action of pudendal nerve electroacupuncture on intermittent claudication and lower limb dysesthesia in addition to any activation of the pain inhibitory system by acupuncture and electroacupuncture.\textsuperscript{10,12} It is of course uncertain whether these effects are prolonged or sufficient to be clinically relevant. However, the effects of electroacupuncture directly to the nerve in this study were much more consistent than the effects of manual stimulation given to the

\begin{figure}
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\caption{Changes in sciatic blood flow due on electrical stimulation of the pudendal nerve. Upper figure: changes in sciatic nerve blood flow (NBF), mean blood pressure (MBP) and heart rate (HR) due to electrical stimulation of the pudendal nerve before administration of atropine (*P<0.05). Lower figure: changes in NBF, MBP and HR on electrical stimulation of the pudendal nerve five minutes after administration of atropine.}
\end{figure}
paravertebral muscles in our previous experiment.\textsuperscript{12} We have to speculate that the chronic pain or numbness in patients with spinal stenosis could be related to impaired blood flow in the sciatic nerve, and that improvement of the blood flow could contribute to the improvement of these symptoms.

The anatomical basis of the findings of our study is still unclear because the innervation of the blood supply to the sciatic nerve from the pudendal nerve is not clearly understood. This would be a suitable topic for further investigation.

**Acknowledgements**

We are grateful to Dr N Ishizaki (The Department of Clinical Acupuncture and Moxibustion, Meiji University of Integrative Medicine) for his valuable suggestions and review of the manuscript.

**Summary box**

Spinal canal stenosis may impede the blood supply to the cauda equina and spinal cord

In rats, electrical stimulation to the pudendal nerve increased blood flow in the sciatic nerve

**Reference list**


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doi: 10.1136/aim.26.3.145

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