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Neuroprotective effects of Potentilla fulgens on spinal cord injury in rats: an immunohistochemical analysis

Short title: Neuroprotective effects of Potentilla fulgens on spinal cord injury

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Abstract

This examination was performed to research the advantage of the antioxidant impact of Potentilla fulgens on spinal cord injury (SCI) in rats. In the SCI model of this examination, the tolerably serious lesion was performed at the L1-L2 spinal segmental level. Spinal cord injury animals were given P. fulgens 400 mg/kg/day, intraperitoneally. At seven days post-lesion, exploratory rats were executed after intraperitoneal administration of ketamine HCL (0.15 ml/100 g body weight). Spinal cord specimens were taken for histological examination or assurance of malondialdehyde (MDA) and glutathione (GSH) levels and myeloperoxidase (MPO) action. SCI caused a remarkable decline in spinal cord GSH content, trailed by noteworthy increments in MDA levels and MPO action. Degenerative changes in some multipolar and bipolar nerve cells and picnotic changes in the nuclei of glial cells were likewise noticed. Remarkable development was seen in cells and vascular structures of P. fulgens treated groups when contrasted with untreated groups. P. fulgens application may influence angiogenetic improvement in vein endothelial cells, reduce inflammatory cell
aggregation by influencing cytokine system and may make apoptotic nerve cells and neuroprotective component in glial cells.

Key words: Spinal cord injury, Potentilla fulgens, VEGF, Bcl-2 (B-cell lymphoma 2)

INTRODUCTION

Most spinal cord lesions are seen on the cervical spine, while devastating motor, sensory and autonomic dysfunctions are causing issues for SCI cervical, thoracic, lumbar, and sacral levels under injury (1). Disturbing lesion in spinal cord starts an enormous resistant reaction which may bring about the apoptosis of neurons and the initiation of glial cells, and the neurological dysfunction. Lesion to the spinal cord prompts irreversible loss of neurons (2,3).

It has been demonstrated that this useful revamping within the dorsal horns comes about because of excessive and non-specific growing of essential afferent sensory fibers, and loss of supraspinal innervations/neurons after lesion (4,5). It has additionally been demonstrated that bruise SCI prompts expanded abundance and broad spreading of essential afferents and that a decrease in the abundance of sensory nerve cells is related to reduced pain after SCI (6). The pathological procedure of SCI can be partitioned into two phases: essential lesion and subordinate lesion. Essential lesion happens instantly after the underlying lesion, and its pathological procedures incorporate demyelination of the spinal cord and necrosis of the neurons and nerve cells (7).

Subordinate lesion happens all through the disease, and its pathological procedures incorporate demyelination, axonal and neuronal necrosis, sensory tissue ischemia and edema, oxidative compression, inflammatory response, and glial scar development (8-12). The essential injury is privately limited to the territory of the vertebral fracture and is distinguished by intense haemorrhage and ischaemia. Subordinate trauma within the first week after the lesion is distinguished by further destruction of neuronal and glial cells, and leads healing to a remarkable extension of the injury, with the goal that the paralysis can reach out to higher sections.

Oxygen-derived free radicals have been embroiled in the pathogenesis of spinal cord neuronal lesion after injury. Reducing the level of oxidative compression limits the subordinate destructive impact after disturbing lesion. After spinal cord lesion, loss of motor, sensory and autonomic sensory system capacities, muscle spasms, chronic pain, urinary tract diseases may happen (13). Both practical (locomotor capacity and bladder function) and
histological parameters (tissue sparing, axonal sparing, astrogliosis, inflammation and BSCB permeability) was enhanced by healing with imatinib following spinal cord weight-drop lesion (14).

_Potentilla fulgens_ is an alpine plant of Western Himalayas which is devoured in all parts of the world for its promising therapeutic properties. Pharmacologically, the aerial and root parts of the plant are accounted for to have antioxidant, antitumor, hypoglycemic and antihyperglycemic components (15-17).

Vascular endothelial growth factor (VEGF) is among the essentially upregulated genes found in SCI rats with allodynia (18). Apoptosis has a noteworthy part in the component of the disturbing lesion in the juvenile brain and is extremely serious in the brain of 7-day-old rats (19). A few examinations have exhibited that over-expression of Bcl-2 (B-cell lymphoma 2) keeps neurons from cell death incited by free radicals (20), hypoxia (21) or development factor deprivation (22). The neuroprotective impact of _P. fulgens_ on neuronal and angiogenetic function after spinal cord injury was examined.

**MATERIALS and METHODS**

**Animals and experimental design**

Every single surgical methodology and the consequent care and healing of the animals utilized as a part of this investigation were in strict understanding with the National Institutes of Health (NIH Publications No. 8023, revised 1978) rules for animal care. All techniques performed in this examination were approved by the Ethics Committee for Animal Experimentation of the Faculty of Medicine at Dicle University, Turkey. Thirty male Sprague-Dawley rats (200–230 g) were kept up under 22±1°C and 12 hrs light/gray cycles with _ad libitum_ access to standard pelleted nourishment and water. The 30 rats were separated into 3 groups as a control group, SCI group and SCI + _P. fulgens_ treated group (400 mg/kg/day, i.p) (23).

The rats of the control (n=10) and the SCI groups (n=10) were administered 1.5 ml physiologic saline solution subcutaneously for 7 days as it were. The rats of all groups were kept up in a similar situation and ate a similar sort of food. All rats toward the finish of the analysis were healthy and no distinction in nourishment/water consumption and body weight pick up amongst experimental and control rats were noticed.
**Spinal cord injury model**

Experimental rats were anesthetized intraperitoneally with ketamine and chlorpromazine 75 mg/kg and 1 mg/kg, separately (24). Every rat was then positioned on a heating pad in a prone position and a rectal test was embedded. Under aseptic conditions, following T5-12 midline skin incision and paravertebral muscle dissection, spinous procedures and laminar arcs of T5-12 were evacuated. The particular relative angulation of the spinous procedures of the T9, T10, and T11 vertebrae was utilized as an imperative intraoperative landmark: T9 points caudally, T10 points directly dorsal, and T11 points rostrally. This delivers a solid "triangle" introduction that can be promptly checked whether the animal is positioned flat on the operating table. After the T11 and T12 vertebrae had been distinguished, a laminectomy was performed at T11 and T12 with Friedman-Pearson rongeurs. The clasp was then held open with a clasp utensil, with the lower cutting edge of the clasp passed extradurally completely around the spinal cord and nerve roots at the intersection between the T11 and T12 vertebrae, comparing to the L1-L2 spinal cord segmental level. The clasp was then quickly discharged from the tool to deliver a bilateral impact force and sustained dorsal-ventral compression. The compression of the spinal cord was kept up for 60 sec before expulsion of the clasp. The muscles were then sutured utilizing 3–0 polyglactin sutures, and the skin was shut with Michel clips (25). Following surgical system, the rats were put in warming chamber and their body temperatures were kept up at roughly 37°C until the point when they were totally conscious. A hour after the spinal cord injury in the exploratory groups, saline only was injected intraperitoneally in rats of the SCI group.

After spinal cord injury, *P. fulgens* (400 mg/kg/day, i.p) was administered intraperitoneally in rats of the SCI+*P. fulgens* treated group during 7 days. Toward the finish of the examination, the animals were sacrificed utilizing a decapitator (Harvard Apparatus, Holliston, MA, USA). The 30 rats were partitioned into three groups as control, SCI and SCI + *P. fulgens* treated groups (400 mg/kg/day, i.p). Each group had 10 animals. All of them were utilized for biochemical parameters and the assessment of histological examination in each group.

**Histologic examinations**

The specimens taken from the spinal cord were fixed with neutral buffered 10% formalin solution. Spinal cord specimens were directly dehydrated in an evaluated solution of ethanol and implanted into paraffin wax; 5 mm sections were cut with a microtome (Rotatory Microtome, Leica, RM 2265, Germany) and mounted on the smeared slides. The segments
were stained with Hematoxyline-Eosin in order to describe the white and the gray matter, separately.

**Immunohistochemical staining**

An antigen-retrieval process was performed in citrate buffer solution (pH 6.0) two times: first for 7 min, and afterward for 5 min in a microwave oven at 700 W. They were permitted to cool to room temperature for 30 min and washed in distilled water twice for 5 min. Endogenous peroxidase action was hindered in 0.1% hydrogen peroxide for 15 min. An ultra V block (Histostain-Plus Kit, Invitrogen, Carlsbad, CA) was connected for 10 min before the use of the primary antibodies (VEGF antibody, mouse monoclonal, 1/200, SantaCruz Biotechnology) and Bcl-2 antibody (mouse monoclonal, 1/100, Abcam) overnight.

The secondary antibody (Histostain-Plus Kit, Invitrogen, Carlsbad, CA) was connected for 15 min. At that point, the slides were exposed to streptavidin-peroxidase for 15 min. Diaminobenzidine (DAB, Invitrogen, Carlsbad) was utilized as a chromogen. Control slides were set up as specified above yet overlooking the primary antibodies. In the wake of counterstaining with Hematoxylene, washing in tap water for 5 min, and in refined water for 2 × 5 min, the slides were mounted.

**Measurement of MPO activity**

The MPO activity levels were measured using the method described by Hillegass et al. (26). Spinal cord tissue specimens were homogenized in 50 mM potassium phosphate buffer with a pH of 6.0 and centrifuged at 41,400 g for 10 min. The pellets were then suspended in 50 mM PB containing 0.5% hexadecyl trimethyl-ammonium bromide (HETAB). After three freeze and defrost cycles, with sonication between cycles, the samples were centrifuged at 41,400 g for 10 min. Aliquots (0.3 ml) were added to 2.3 ml of the response mixture containing 50 mM PB, o-dianisidine, and 20 mM H$_2$O$_2$ solution. One unit of enzyme action was characterized as the measure of MPO presence that caused an adjustment in absorbance, estimated at 460 nm for 3 min. MPO action was expressed as U/g tissue.

**Malondialdehyde (MDA) and Glutathione (GSH) assays**

Spinal cord tissue samples were homogenized with super cold 150 mM KCl for the assurance of MDA and GSH levels. The MDA levels were tested for the products of lipid peroxidation and the outcomes are expressed as nmol MDA/g tissue (27).
GSH was resolved by a spectrophotometric technique in light of the utilization of Ellman's reagent and the outcomes are expressed as μmol GSH/g tissue (28).

**Statistical analysis**

All information are expressed as means ± S.D. Groups of information were contrasted and an analysis of variance (ANOVA) trailed by Tukey's various correlation samples. Estimations of p < 0.05 were considered as remarkable.

**RESULTS**

In this study, control, SCI and SCI+P. fulgens treated groups were analyzed as far as biochemical data. MPO action, which is acknowledged as an indicator of neutrophil infiltration, was fundamentally higher in the spinal cord tissues of disturbed rats than those of the control group (p<0.001). P. fulgens healing fundamentally reduced spinal cord tissue MPO levels (p<0.01). The injury caused a noteworthy increment in the MDA levels (p<0.001) with an attending reduction in GSH levels (p<0.001). P. fulgens healing fundamentally decreased the increase in MDA levels and reestablished the GSH content at day 7.

**Table 1. Biochemical results relevant to the study groups.**

<table>
<thead>
<tr>
<th></th>
<th>Control</th>
<th>SCI</th>
<th>SCI+P.Fulgens</th>
</tr>
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<tbody>
<tr>
<td>MDA (nmol/g)</td>
<td>30.45±0.72</td>
<td>47.64±0.66***</td>
<td>33.24±0.82+++</td>
</tr>
<tr>
<td>GSH (µmol/g)</td>
<td>2.65±0.08</td>
<td>1.84±0.04***</td>
<td>2.62±0.07+++</td>
</tr>
<tr>
<td>MPO (U/g)</td>
<td>4.52±0.02</td>
<td>7.82±0.62***</td>
<td>7.92±0.28++</td>
</tr>
</tbody>
</table>

Values are represented as mean ± SD. Each group consists of ten rats.

* p<0.05, versus control
*** p<0.001, versus control
++p<0.01, SCI + P. fulgens treated group
+++p<0.001, SCI + P. fulgens treated group
In spinal cord samples of the control group, the nuclei of multipolar neurons with polygonal appearances in the foremost part of the gray matter layer demonstrated rough chromatin and the nerve expansions were scattered in parallel. Glial cells with oval nuclei were seen in the white matter and the axonal and dendritic expansions were orderly. In the SCI group, mononuclear cell infiltration was seen around the vessels, and in addition dilatation and discharge of the veins were seen along the pia mater and in the veins, in the foremost median fissure of the spinal cord. Degenerative changes in a portion of the multipolar and bipolar nerve cells and picnotic changes in the nuclei of glial cells were noticed.

The histopathological examination of SCI+P. fulgens treated groups uncovered minor hemorrhagic sections with decreased inflammatory cells in the gray and the white matter, slight degeneration in multipolar and bipolar cells, and hypertrophic glial cells were likewise noticed. Immunohistochemical examinations of the control group indicated VEGF positive expression in the assortments of multipolar neurons in the foremost part of the spinal cord while it was somewhat expressed in minor fine and vascular endothelial cells. In the spinal cord lesion injury, expanded VEGF expression was seen in the endothelial cells of vessels in the gray and the white matter layers.

Positive VEGF expression were likewise found in some nerve cells and glial cells. In the SCI + P. fulgens treated group, VEGF expression in the vascular endothelium was positive. Conversely, it was feeble in the glial cells and a portion of the radicular and funicular cells in the gray and the white matter. In the control group of Bcl-2 expression, negative Bcl-2 immunoreaction was seen in the radicular-funicular nerves and the glial cells.
In the SCI group, positive Bcl-2 immunoreaction was seen in apoptotic cells, in minor unipolar neurons, and in glial cells. In SCI + \textit{P. fulgens} treated group, apoptotic changes were seen in bipolar and unipolar neurons, yet Bcl-2 expression surfaces were not as much as the SCI group.
Figure 1a- Control group. The nuclei of multipolar neurons with polygonal appearances at the front of the gray matter layer shows coarse chromatin (red arrow) and the nerve extensions are distributed in parallel, the round nucleus of the glial cells (yellow arrow) in the white matter, the axonal and the dendritic extensions are regular (Hematoxyline-Eosin staining Bar 50 µm), 1b- SCI group. Dilatation and hemorrhagie in a blood vessel (yellow arrow), degeneration and nuclear piconsis in radicular (black arrow), funicular neuron cells (red arrow) (Hematoxyline-Eosin staining Bar 50 µm), 1c- SCI+ P. fulgens treated group. Small hemorrhagic segments (yellow arrow) with reduced inflammatory cells in the gray and the white matter, slight degeneration in multipolar (red arrow) and bipolar cells (black arrow), and hypertrophic glial cells (green arrow) (Hematoxyline-Eosin staining Bar 50 µm), 1d- Control group. VEGF positive expression in multipolar neurons (yellow arrow) and vascular endothelial cells (red arrow) VEGF immunostaining Bar 50 µm, 1e- SCI group. An increase of VEGF expression in endothelial cells (yellow arrow), positive VEGF expressions in some nerve cells and glial cells (red arrow), VEGF immunostaining Bar 50 µm, 1f- SCI + P. fulgens treated group. Positive VEGF expression in the vascular endothelium (red arrow), weak VEGF expression in glial cells (yellow arrow) and some of the radicular and funicular
cells (black arrow), VEGF immunostaining Bar 50 µm, 1g-Control group. Negative Bcl-2 immuno-reaction in radicular-funicular nerves (red arrow) and glial cells (yellow arrow), Bcl-2 immunostaining Bar 50 µm, 1h- SCI group. Positive Bcl-2 expression in apoptotic cells, small unipolar neurons (red arrow) and glial cells (yellow arrow), Bcl-2 immunostaining Bar 50 µm, 1h- SCI + P. fulgens treated group. Decrease in the quantity of Bcl-2 expression in unipolar neurons (red arrow), and glial cells (yellow arrow), Bcl-2 immunostaining Bar 50 µm.

DISCUSSION

Spinal cord lesion is typical a disturbing lesion to the central nervous system which can bring about tissue and motor dysfunction accompanied by molecular and cellular injury after trauma. Spinal cord lesion brings about a fast and broad oxidative compression. It has for quite some time been built up that oxidative compression assumes a significant part in the pathophysiology of SCI (29-31). The utilization of animal models is significant in formulating experimental healings planned to restore lost functions due to SCI (3).

Receptive astrocytes likewise assume a vital part in lesion healing and practical recuperation after SCI. At the subacute stage, astrocytes relocate to compact the injury, apparently detaching the inflammatory cells to keep them from spreading into the parenchyma of the spinal cord. The essential function of astrocytes was at first an idea to buffer and supply neurons, however, these days there is a lot of confirmation demonstrating that astrocytes are firmly connected with microglia, oligodendrocytes, and different astrocytes in the nervous system. Astrocytes direct neurotransmitters, take an interest in synaptogenesis, mediate the antibody, express extracellular matrix molecules, advanced cell migration, and advanced separation and development of the central nervous system (32).

Apoptosis causes the death of neuronal cells, particularly neurons and oligodendrocytes in the spinal cord after lesion, and further upsets and annihilates the axon-myelin anatomical unit and disables impulse conduction, bringing about neuronal loss (33,34). A period course investigation in rats uncovered that apoptosis happened as ahead of schedule as 4 hrs post lesion and could be seen in decline amount as late as 3 weeks after SCI. After SCI, caspase initiation happens in neurons at the lesion site within hours, and in oligodendrocytes neighboring, and far off from, the lesion site over a time of days. The long duration neurological shortages after spinal cord lesion might be expected to a limited extent to far reaching apoptosis of neurons and oligodendroglia in regions far off from and generally unaffected by the underlying lesion (35).
Özеврен et al. (36) detailed that *P. fulgens* may anticipate nerve cell injury after traumatic brain lesion, contingent upon the measure of application. Vascular endothelial growth factor (VEGF) is a contributing component in the advancement of vascularization amid angiogenesis and spinal cord lesion. In any case, the neuroprotective mechanism of VEGF is as yet uncertain. A few examinations have demonstrated that the administration of VEGF to the wounded spinal cord has neuroprotective impacts, induces angiogenesis and enhances neurobehavioral outcomes (37,38).

Herrera et al. (39) demonstrated that VEGF is regularly expressed in neurons and astrocytes. They felt that neurons at the site of lesion 1 day after spinal cord lesion were significantly lost and could add to a general reduction in VEGF. After spinal cord lesion, VEGF expression was seen to be sure in some nerve cells and glial cells, an expansion in VEGF immuno-response in vascular endothelial cells was noticed. For this situation, angiogenesis was believed to be actuated in endothelial cells after lesion. One investigation demonstrated that the over-expression of Bcl-2 by gene transfer or in transgenic mice decreased infarction after permanent and transient central ischemia. Expression of the apoptosis-inhibitory Bcl-2 gene under the control of tissue particular promoters has turned out to be equipped for shielding different sorts of cells from apoptosis, especially motor neurons of the spinal cord (40).

The glutathione/glutathione disulphide (GSH/GSSG) redox framework is a noteworthy contributor to the upkeep of the cellular thiol redox status. Confirmation demonstrated that the decrease in cell GSH was related to upgraded cellular apoptosis while increments in GSH were related to the expression of the anti-apoptotic enzyme, Bcl-2 (41). As indicated by the outcomes of this investigation, reduction in apoptotic cell quantity of nerves and glial cells, and furthermore reduction in the Bcl-2 immunoreactivity was considered as an indication of cell upturn in apoptosis mechanism.

Tas et al. (42) found that neuronal injury impacted astrocytes in the blood-brain obstruction and initiated cellular apoptosis. Kannoet al. (43) found that autophagic cell death was incited in the wounded tissue after SCI and plainly added to neural tissue injury after SCI.

After spinal cord lesion, inflammation of the spinal cord and impeded vascular structure, apoptotic changes of neurons, and dynamopathetic healing are a vital procedure. At the point when apoptosis of neurons and glial cells is counteracted after lesion, the loss of nerve tissue can be fundamentally lessened and spinal cord lesion may improve. Inflammatory reactions are a noteworthy component of the secondary lesion and they assume a focal part in controlling the pathogenesis of intense and chronic SCI and appears to assume a significant
part in nerve lesion and in addition adds to the control of the regenerative reaction (44). In the interim, inflammatory reactions may bring about apoptosis of neurons and oligodendrocytes and also in scar formation and lastly in the decrease of neuronal capacity (45). Hence, it is trusted that decreasing inflammation could reduce subordinate degeneration and the useful deficiency after SCI.

All in all, *P. fulgens* administration after spinal cord injury reduced apoptotic cell quantity of nerves and glial cells. Since it impacted the cytokine mechanism, it supposedly decreased the quantity of inflammatory cells and incited angiogenetic advancement. With the distinguishing proof of mechanisms that counteract spinal cord inflammation and apoptosis come new methodologies for avoiding and treating spinal cord injury. Be that as it may, there is no present strategy for healing of spinal cord injury. There is a requirement for more experimental examinations on the dose quantity and span of healing of *P. fulgens* in SCI. Thusly, therapeutic impact on spinal cord injury will be better comprehended later on.

**REFERENCES**


