The Spine Journal 14 (2014) 1005–1009

Basic Science

# Neural reflex pathway between cervical spinal and sympathetic ganglia in rabbits: implication for pathogenesis of cervical vertigo

Jinliang Zuo, MD[a,*], Jianlong Han, MS[a], Siqiang Qiu, MS[a], Fanghai Luan, MS[a], Xinwei Zhu, MS[a], Haoyuan Gao, BS[a], Anmin Chen, PhD[b]

[a]*Department of Orthopedics, The 4th Hospital of Jinan, 50 Shifan Rd, Jinan, Shandong Province 250031, China*
[b]*Department of Orthopedics, Tongji Hospital, Tongji Medical College, Huazhong University of Science and Technology, 1095 Jiefang Ave, Wuhan, Hubei Province 430030, China*

Received 7 February 2013; revised 25 September 2013; accepted 21 November 2013

**Abstract**

**BACKGROUND CONTEXT:** A functional association between cervix and vertigo has been observed in patients with cervical vertigo, implicating correlation between cervical spinal and sympathetic ganglia. However, it is unclear where there is an anatomic connection between those two groups of ganglia.

**PURPOSE:** This study aimed to investigate the existence of the neural connections between cervical spinal and sympathetic ganglia.

**STUDY DESIGN/SETTING:** FluoroGold staining patterns in cervical spinal and sympathetic ganglia were evaluated using FluoroGold retrograde tracing in New Zealand rabbits.

**METHODS:** New Zealand rabbits were randomly divided into superior cervical spinal ganglion injection groups, inferior cervical spinal ganglion injection groups, superior cervical sympathetic ganglion injection group, and inferior cervical sympathetic ganglion injection group. Four percent FluoroGold solution was injected into these ganglia. Distribution of FluoroGold in cervical spinal and sympathetic ganglia was observed under a microscope.

**RESULTS:** When FluoroGold solution was injected into C2 and C3 superior cervical spinal ganglia or C5–C6 inferior cervical spinal ganglia, fluorescence was only observed in the ipsilateral superior or inferior cervical sympathetic ganglia, respectively. When FluoroGold solution was injected into superior or inferior cervical sympathetic ganglia, fluorescence was found mainly in the ipsilateral C3–C4 superior or C5–C8 inferior spinal ganglia. No fluorescence was observed in contralateral ganglia of experimental animals and all ganglia of matched control animals injected with physiological saline.

**CONCLUSIONS:** Bidirectional nerve fiber connections between cervical spinal and sympathetic ganglia were observed, and these connections are arranged in a segmental distribution. This observation may provide a possible neuroanatomic basis for the pathogenesis of cervical vertigo. 

*Keywords:* Cervical spinal ganglion; Cervical sympathetic ganglia; FluoroGold; Cervical vertigo; Reflex arc; Retrograde labeling

## Introduction

Dizziness and/or vertigo (collectively termed cervical vertigo) can accompany a variety of neck disorders, including whiplash [1]. The prevalence of cervical vertigo among patients with neck disorders caused by whiplash injury ranges from 25% to 50% [2]. The mechanism underlying this phenomenon is unknown. One potential mechanism is stenosis or spasm of the vertebrobasilar artery system

FDA device/drug status: Not applicable.

Author disclosures: ***JZ:*** Grant: The Key Scientific and Technological Project of Jinan (D, Paid directly to institution). ***JH:*** Nothing to disclose. ***SQ:*** Nothing to disclose. ***FL:*** Nothing to disclose. ***XZ:*** Nothing to disclose. ***HG:*** Nothing to disclose. ***AC:*** Nothing to disclose.

The disclosure key can be found on the Table of Contents and at www.TheSpineJournalOnline.com.

The study was financially supported by the Key Scientific and Technological Project of Jinan (Project No. 062163).

* Corresponding author. Department of Orthopedics, The 4th Hospital of Jinan, Jinan 250031, China. Tel.: (86) 15105316966; fax: (86) 0531-85800741.

*E-mail address*: zjl.md@163.com (J. Zuo)

1529-9430/$ - see front matter 
http://dx.doi.org/10.1016/j.spinee.2013.11.031

[3]. The vertebral arteries are mainly innervated by nerve fibers from the cervical sympathetic ganglia [4]. A neural connection between cervical spinal and sympathetic ganglia would provide an anatomic substrate for cervical vertigo with cervical lesion. The present retrograde tracing study was conducted to clarify the inherent neural pathways between cervical and sympathetic ganglia and their possible involvement in the development of cervical vertigo.

## Materials and methods

### *Animals and experimental groups*

One hundred five New Zealand rabbits (weight, 2.5–3.0 kg) were randomly divided into superior cervical spinal ganglion injection groups (defined as C2 and C3, with 10 rabbits in each group), inferior cervical spinal ganglion injection groups (defined as C4–C6, with 10 rabbits in each group), superior cervical sympathetic ganglion injection group (N=10), inferior cervical sympathetic ganglion injection group (N=10), and corresponding control groups (N=5 in each control group). The use of experimental animals was approved and supervised by the Institutional Animal Welfare and Research Committee.

### *Surgical technique*

The rabbits were placed in the prone position on the laboratory table, and anesthesia was induced by intravenously administering chloral hydrate (60 mg/kg). Corresponding cervical spinal and sympathetic ganglia were exposed under sterile conditions. Four percent FluoroGold solution (Fluorochrome LLC, Denver, CO, USA) was injected into the proper ganglia at a dose of 2 μL per ganglion, and a physiological saline solution was injected into the ganglia of the control rabbits. The injection was performed slowly, and the needle was retained in the spinal ganglia for 5 minutes to avoid tracer overflowing from the injection site. The rabbits were then fed and allowed activity ad libitum for 14 days. Thirteen rabbits died intraoperatively or during the 2-week study period and were replaced with new animals from the same source. All surgical steps were taken carefully to avoid animals' suffering during the experiments.

### *Preparation of slides*

Rabbits were anesthetized as described previously and killed using perfusion with physiological saline. Rapid perfusion through the left ventricle with physiological saline was followed by slow perfusion with 10% formalin at 37°C. The combined perfusion time was about 1 hour. Immediately after perfusion, cervical spinal and sympathetic ganglia were cut, postfixed in the formalin stationary liquid for 6 hours, and placed in 10% sucrose until they were completely submersed. Thirty-micrometer thick cryosections were cut, placed in 0.1% phosphate buffer (containing 5% sucrose), and immediately placed in distilled water to prevent the fluorescent dye overflowing from the cells.

### *Observation of slides*

Each section was directly observed under a fluorescence microscope (OLYMPUS BX5, Olympus Inc., Tokyo, Japan;

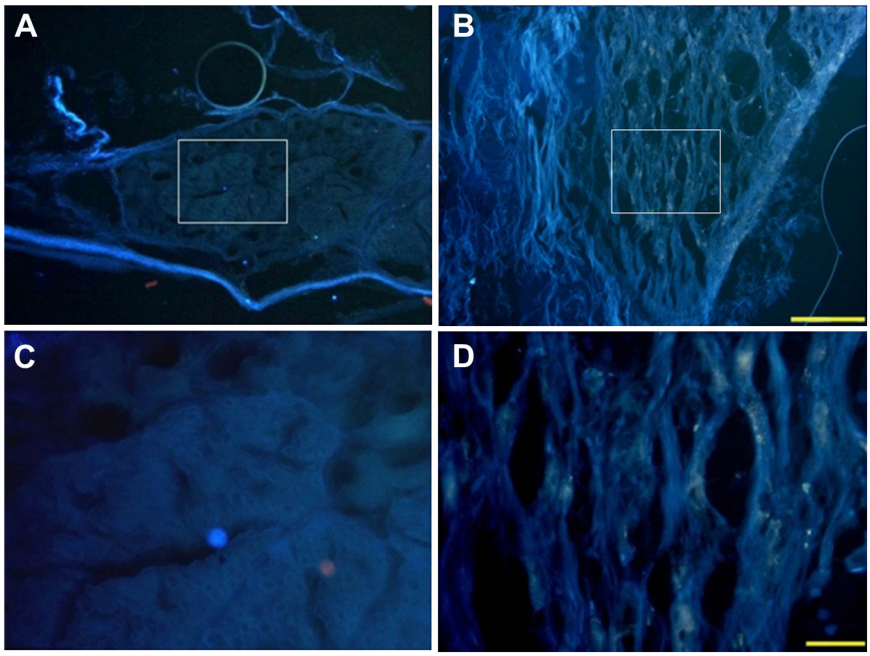


Fig. 1. No FluoroGold-labeled cells were observed in contralateral cervical sympathetic ganglia after the injection of FluoroGold into cervical spinal ganglia (A, C); FluoroGold-labeled cells were observed in ipsilateral cervical sympathetic ganglia after the injection of FluoroGold into cervical spinal ganglia (B, D). The squares in panels A and B indicate the areas for panels C and D separately. Scale bar: A, B: 100 μm; C, D: 20 μm.