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Research paper

# Influence of sympathetic fibers on noise-induced hearing loss in the chinchilla

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**Abstract**

The influence of the sympathetic efferent fibers on cochlear susceptibility to noise-induced hearing loss is still an open question. In the current study, we explore the effects of unilateral and bilateral Superior Cervical Ganglion (SCG) ablation in the chinchilla on hearing loss from noise exposure, as measured with inferior colliculus (IC) evoked potentials, distortion product otoacoustic emissions (DPOAE), and outer hair cell (OHC) loss. The SCG was isolated at the level of the bifurcation of the carotid artery and removed unilaterally in 15 chinchillas. Another eight chinchillas underwent bilateral ablation. Twelve animals were employed as sham controls. Noise exposure was a 4 kHz octave band noise for 1 h at 110 dB SPL. Results showed improved recovery of DPOAE amplitudes after noise exposure in ears that underwent SCGectomy, as well as lower evoked potential threshold shifts relative to sham controls. Effects of SCGectomy on OHC loss were small. Results of the study suggest that sympathetic fibers do exert some influence on susceptibility to noise, but the influence may not be a major one.


*Keywords:* Superior cervical ganglion; Noise; DPOAE; Cochlea; Sympathetic

## 1. Introduction

An individual's inherent susceptibility noise-induced hearing loss (NIHL) is influenced by numerous factors, including the influence of efferent projections to the cochlea (Zheng et al., 1997; Zheng et al., 2000; Le Prell et al., 2003; Hildesheimer et al., 1991; Hildesheimer et al., 2002). The efferent nerve supply to the cochlea includes two categories of fibers, the lateral and medial olivocochlear efferent fibers, which terminate on the afferent dendrites under the inner hair cells and on the outer hair cells (OHC), respectively. Along with the olivocochlear efferent fibers, there is a supply of sympathetic adrenergic efferent fibers projecting to the cochlea. The sympathetic fibers originate ipsilaterally from the superior cervical ganglion (SCG) and bilaterally from the stellate ganglion (SG). Identified several decades ago by Spoendlin and Lichtensteiger (1966), the sympathetic fibers were separated into two classes, perivascular and non-perivascular. The perivascular fibers innervate smooth muscle tissue surrounding arterioles that supply the cochlea (Spoendlin and Lichtensteiger, 1966; Spoendlin, 1981; Brechtelsbauer et al., 1990). Through modulation of arteriole diameter, the perivascular fibers have a significant effect on cochlear blood flow (CBF) (Brechtelsbauer et al., 1990; Laurikainen et al., 1993; Ren et al., 1993; Laurikainen et al., 1997). The perivascular fibers derive mainly from the SG, with a minor contribution from

*Abbreviations:* SCG, superior cervical ganglion; IC, inferior colliculus; DPOAE, distortion product otoacoustic emissions; OHC, outer hair cells; NIHL, noiseinduced hearing loss; SG, stellate ganglion; CBF, cochlear blood flow; CAP, compound action potential; TTS, temporary threshold shift; PTS, permanent threshold shift; EVP, evoked potential; TDT, Tucker Davis technologies

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the SCG. Unilateral chemical blockade of the SG with lidocaine led to a transient 10–15% increase in ipsilateral CBF, and a prolonged increase in contralateral CBF of as much as 25–35% (Laurikainen et al., 1997). Stimulation of the SCG caused an approximately 12% decrease in CBF on the ipsilateral side. Transection of the SCG did not have any significant effects on tonic CBF levels (Laurikainen et al., 1997). Additionally, transection of the SCG enhanced increases in CBF evoked by electrical stimulation of the cochlea. Stimulation of the SCG during electrical stimulation of the cochlea almost completely abolished any increases in CBF that are normally seen (Laurikainen et al., 1993). The data point to a role for the SCG in CBF in response to stimulation of the cochlea, but not an effect on resting CBF.

The role of the non-perivascular sympathetic fibers, which are dense in the cochlea near the habenula perforata, in cochlear homeostasis and response to noise, is unknown. Electrical stimulation of the sympathetic trunk of the SCG led to increases of 15–20% in amplitude of the N1 wave of the compound action potential (CAP) (Pickles, 1979). Lee and Moller (1985) found increased variability in the amplitude of N1 after sympathetic stimulation. Some of their animals showed increased amplitude, some showed decreased amplitude, and some showed no change. They did find increases in latency of the N1 response after sympathetic stimulation (Lee and Moller, 1985). Results from SCGectomy have shown a significant decrease in CAP maximum amplitude after the surgery (Hultcrantz et al., 1982). Collectively, the findings suggest a modulatory effect of the SCG fibers on the afferent auditory nerve signal, although the magnitude of the effect is still unclear.

Past studies have examined how the fibers from the SCG have influenced susceptibility to NIHL. The studies have found decreases in vulnerability to NIHL after transection of the SCG in rats (Borg, 1982) and decreased vulnerability to temporary threshold shift (TTS) (Hildesheimer et al., 1991; Horner et al., 2001) and permanent threshold shift (PTS) (Hildesheimer et al., 2002) after SCG transection in guinea pigs. The magnitude of the effects varied between the studies. The differences between the past studies may be due to species differences or differences in the type of noise exposure given. Clarification of these differences would be useful in further delineating the role of the sympathetic fibers in influencing NIHL susceptibility.

The current study was designed to examine the effects of SCGectomy on susceptibility to NIHL in the chinchilla animal model. While past studies have demonstrated that ablating the SCG can lead to decreased susceptibility to NIHL (Borg, 1982; Hildesheimer et al., 1991, 2002; Horner et al., 2001), the studies have inconsistent findings with respect to effect of unilaterally ablating the SCG. Decreased susceptibility to noise has been observed in ears ipsilateral to unilateral SCGectomy (Borg, 1982). Hildesheimer et al. (1991) found no protective effect of unilateral SCGectomy, but did find protection from bilateral SCGectomy (Hildesheimer et al., 1991). Horner et al. (2001) found contralateral protection from an ipsilateral SCGectomy. While the SG has bilateral projections to the cochlea, the SCG does not. Yet, the noise protection studies that used SCGectomy have yielded results suggesting a bilateral influence of the ipsilateral SCG. In order to attempt to further elucidate the role of the SCG in susceptibility to noise, the current study examined three groups of animals with respect to susceptibility to NIHL:

1. Animals with unilaterally ablated SCGs.
2. Animals with bilaterally ablated SCGs.
3. Animals with unilateral sham SCGectomy.

Clarification of the influence of the SCG fibers on susceptibility to noise allow for future comparison with the effects of blockade of the SG fibers through surgical or chemical means, thus permitting a more complete understanding of the sympathetic system's involvement in NIHL.

## 2. Materials and methods

Thirty-five adult chinchillas were used as subjects. Prior to surgical procedures and between test times, the animals were housed in a quiet colony. All procedures involving use and care of the animals were be reviewed and approved by the State University of New York at Buffalo Institutional Animal Care and Use Committee.

### 2.1. SCGectomy surgery

For the SCGectomy surgery, the chinchillas were intramuscularly injected with ketamine (60 mg/kg) and acepromazine (0.5 mg/kg) to achieve deep anesthesia. A ventral incision was made at the level of the bifurcation of the carotid artery. Using an operating microscope, the carotid artery was visualized. The SCG was then identified under a microscope. The SCG runs deep to the carotid. The ganglion and its branches were isolated and removed. Removal of some fatty tissue was often necessary to properly visualize and remove the ganglion. Care was taken not to disrupt the Vagus or Accessory nerves that run near the SCG and its branches. Finally, the incision was sutured. For bilateral SCGectomy, the procedure was repeated on the side contralateral to the initial surgery. For sham controls, the ganglion was located and visualized, but not removed.

Animals that underwent successful SCGectomy exhibited signs of Horner's syndrome, a series of physiological disturbances that affect the eye resulting from loss of sympathetic innervation. The most notable of the signs of Horner's syndrome are eye retraction into the socket, ptosis, and miosis (Amonoo-Kuofi, 1999).

### 2.2. Chronic electrode implantation

Following the SCGectomy surgical procedures, while still under the anesthesia from the SCGectomy procedure, the animals were also implanted with chronic recording