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# Bilateral superior cervical sympathectomy and noise-induced, permanent threshold shift in guinea pigs

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**Abstract**

The rich sympathetic innervation to the cochlea suggests its potential control of cochlear blood flow and activity during noise exposure, as part of the general and local stress sympathetic reaction evoked by noise. In a previous study, superior cervical sympathectomy prior to sound exposure in guinea pigs in an awake state, resulted in reduced temporary threshold shift. The present study was conducted to explore whether this potential protection would also be manifested in conditions producing permanent threshold shift (PTS). Thirty-six guinea pigs, divided into four groups of nine guinea pigs each, were sound exposed for 2 h in an awake state. Eighteen guinea pigs underwent superior cervical sympathectomy prior to sound exposure. Auditory brainstem thresholds were recorded prior to sound exposure, and then at 24 h, 1 and 6 weeks post-exposure. Results indicated a reduced PTS at 122 dB sound pressure level (SPL) exposure, suggesting a protective effect of the sympathectomy. However, at 125 dB SPL exposure, the protective effect was reduced. 

*Key words:* Permanent threshold shift; Temporary threshold shift; Cochlear sympathetic innervation; Noise; Stress

## 1. Introduction

Investigators studying the noxious effect of stress on different body systems use noise exposure as a definite general body stress-inducing stimulus. For example, cardiovascular researchers use different sound stimuli as stressors (Breschi et al., 1994; Langewitz et al., 1994). Borg (1982), at the time of investigating the damaging effect of noise on the ear, referred to the general body startle–alerting reaction evoked by noise, in which a sympathetic discharge is responsible for many different effects on the body. The effects include, among others, blood circulation, vasoconstriction of peripheral blood vessels, and changes in normal gastrointestinal motility. The organism attempts to maintain function through change, and the sympathetic nervous system (SNS) responds by an adaptive allostatic reaction to noise exposure in awake states (McEwen, 1998). The rich sympathetic innervation to the cochlea (Spoendlin and Lichtensteiger, 1966; Spoendlin, 1981) suggests, as postulated by Borg (1982), its potential activity during noise exposure in awake states as part of the general and local sympathetic reaction evoked by noise.

Studies on the SNS in the cochlea are scarce and results are controversial (Wada et al., 1999). The adrenergic control of cochlear blood flow was investigated already in the 1960s (Perlman et al., 1963; Suga and Snow, 1969; Suga, 1976). Since then, accumulated literature has shown evidence supporting its control of cochlear blood flow (Brechtelsbauer et al., 1990; Ren et al., 1993; Laurikainen et al., 1993, 1997).

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*Abbreviations:* ABR, auditory brain stem response; ANOVA, analysis of variance; PTS, permanent threshold shift; SNS, sympathetic nervous system; SPL, sound pressure level; TS, threshold shift; TTS, temporary threshold shift

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For many years, the controversy of cochlear blood flow involvement in the damaging effect of noise exposure on the cochlea has also been dealt with extensively in the literature (Hawkins, 1970; Hulcrantz et al., 1979; Axelsson et al., 1981; Thorne and Nuttall, 1987; Ryan et al., 1988). Recent research findings confirm cochlear blood flow reactivity to noise exposure (Quirk and Seidman, 1995). Furthermore, acoustic stimulation increases cochlear energy metabolism, which may result in localized ischemia and subsequent release of reactive oxygen species that contribute to cochlear damage (Ohinata et al., 2000). Manipulation of blood or oxygen supply to the ear could alter the noise-induced threshold shift (TS) (Kellerhals, 1972; Miller et al., 1983; Hatch et al., 1991; Goldwyn et al., 1998). The controversy on the function of the SNS in the cochlea extended to the role of the cochlear SNS in noise over-stimulation. Wada et al. (1999) suggested a protective value to electrical stimulation of the ipsilateral cervical SNS, and did not observe any effect after surgical elimination of the superior cervical ganglion compared to a non-treated condition during sedation. In their study, the heart rate and blood pressure were not elevated during sound exposure that was performed during deep sedation. Wada et al. (1999) explained that it is likely that the reason for no change in TS in animals that surpassed SNS elimination compared to controls is due to the sufficient suppression of SNS activity in the control animals by pentobarbital administration. On the other hand, Horner et al. (2001) inactivated the sympathetic system by transection of the ipsilateral superior cervical ganglion in guinea pigs. Their results suggest that sympathetic input to the cochlea can influence the extent of protection against noise. The general body SNS activity and cochlear sympathetic activity during noise exposure in awake states, with their potential to control blood flow that influences the noise-induced damage, were the bases for conducting our previous study (Hildesheimer et al., 1991). In line with the idea of Borg (1982), we demonstrated that short, high-intensity sound exposure in awake guinea pigs induced less temporary threshold shift (TTS) in those that underwent bilateral cervical ganglion sympathectomy prior to sound exposure. A protective value in stressful sound exposure conditions was attributed to cervical sympathectomy.

It is known that a habituation process, a gradual adaptation to the stressing stimulus, may be associated with long-lasting stress conditions (Sawada, 1993). Therefore, the present study was conducted to explore whether superior cervical sympathectomy also has a protective effect in permanent threshold shift (PTS) that results from longer-lasting and higher intensity sound exposure.

Two intensity levels for sound exposure were used to induce the TS, i.e., 122 dB sound pressure level (SPL) and 125 dB SPL. The higher intensity level was used to explore whether sympathectomy has a protective effect at higher intensities at which, in addition to a metabolic component, a potentially mechanical component may also be involved in the damaging mechanism (Levine et al., 1998).

## 2. Materials and methods

### 2.1. Sound exposure

Thirty-six inbred Hartley albino female guinea pigs, 7–9 weeks old, weighing 380–450 g were used. They were divided into four groups of nine guinea pigs each. All guinea pigs were exposed for 2 h to 4 kHz pure tone. The exposure intensity was 125 dB SPL for groups 1 and 2 and 122 dB SPL for groups 3 and 4. The guinea pigs in groups 2 and 4 underwent bilateral superior cervical sympathectomy (Hildesheimer et al., 1991) 1 week prior to sound exposure.

Sound exposure took place in a sound-proof room. The SPL of the exposure was measured at the location of the guinea pig. The guinea pigs were awake. To ensure that precise stimulus SPL reached the ear, they were restrained, including head fixation, and were placed in a specific spot in the sound-proof room. The sound was generated by an AM–FM sweep pulse function generator Model 200 MSPC, amplified by a crown D-75 amplifier, and delivered by a loudspeaker-Electro-voice Model SP 12 B.

The power spectrum level of the 4 kHz tone delivered to the loudspeaker was controlled by a sound-level meter B and K 220 G.M 1/3 octave filter set 1625. In the sound-proof room, the noise surrounding the amplification system was monitored during all experiments and was less than 30 dB SPL.

### 2.2. Auditory brain stem response (ABR) threshold assessment

Threshold was evaluated by recording ABRs. Subdermal, stainless steel thin wire electrodes were inserted, one in the scalp and one in the pinna. A ground electrode was inserted on the back of the guinea pigs. The ABR threshold was established by tracking wave N2 in the ABR response as the intensity decreased from 100 dB SPL, initially in steps of 10 dB, followed by a decrease in steps of 5 dB near threshold, until no consistent responses could be recorded. The stimuli for evoking the ABR were tone bursts. The pure-tone bursts (2 ms rise and fall time, 50 ms duration) were at the frequencies of 4, 6 and 8 kHz, and were delivered at the rate of 11/s. The recorded response was the average of